

**THE EFFECTS OF LENTILS AS LOW GLYCEMIC, HIGH PROTEIN
PRE-EXERCISE MEALS ON METABOLISM AND PERFORMANCE DURING
A SIMULATED SOCCER TOURNAMENT**

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ABSTRACT

Research investigating the effects of pre-exercise meals with varying glycemic indices on exercise performance in intermittent sports is scarce. This study determined whether whole foods of low glycemic index (GI) resulted in a metabolic and performance advantage, in comparison to high GI foods, when eaten prior to extended intermittent cardiovascular exercise, such as tournament soccer play. Consenting trained participants (10 males, 4 females, 25.8 ± 7.3 y) completed two simulated soccer tournaments separated by at least seven days. Each testing day included two 90-minute soccer matches separated by a three hour break. Using a randomized cross-over design, low-GI, lentil-based meals (GI~42) or high-GI, potato-based meals (GI~78) matched for caloric value were consumed two hours prior to and then within one hour after the first soccer match. Blood glucose, lactate, insulin, free fatty acids, and respiratory gases were measured throughout the post-prandial and testing periods. Ratings of perceived exertion (RPE) and gastrointestinal symptoms were also recorded. Performance was measured by the distance covered during five one-minute sprints, separated by two minute and thirty second rest intervals, at the end of each match. Peak post-prandial blood glucose was higher ($p < 0.05$) in the high-GI trial ($8.9 \pm 2.2 \text{ mol} \cdot \text{L}^{-1}$ [SD]) compared to the low GI trial ($5.9 \pm 1.3 \text{ mmol} \cdot \text{L}^{-1}$) as was insulin prior to the start of exercise (19.4 ± 2.0 versus $9.2 \pm 1.3 \text{ umol} \cdot \text{L}^{-1}$, $p < 0.05$). Blood lactate levels were significantly higher ($p < 0.05$) at the end of the second match during the high-GI trial ($6.1 \pm 1.2 \text{ mmol} \cdot \text{L}^{-1}$) compared to the low-GI trial ($2.5 \pm 0.4 \text{ mmol} \cdot \text{L}^{-1}$). Breath-by-breath analysis showed lower ($p < 0.05$) carbohydrate oxidation during the low-GI trials compared to the high-GI at the start of the first soccer match ($p < 0.05$). Subjects reported greater feelings of hunger during the high-GI trial versus greater feelings of fullness during the low-GI trial ($p < 0.05$), but RPE during the low-GI (14.1 ± 0.3) was similar to the high-GI meal (14.2 ± 0.3). Sprint distance was not significantly different between treatments ($p = 0.27$). Overall, these findings suggest that lentil-based, low-GI foods are a comparable alternative to traditional high-GI pre-exercise meals, as they result in similar performance outcomes but improved metabolic profiles. Over the long-term, improving metabolic conditions during exercise may be beneficial to the health of athletes.

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ABBREVIATIONS

↓ – decreased	km·hr ⁻¹ – kilometers per hour
↑ – increased	LGI – low glycemic index
AMDR – acceptable macronutrient distribution range	LIST SR – Loughborough Intermittent Shuttle Test Shuttle Run
ATP – adenosine triphosphate	mL·kg ⁻¹ ·min ⁻¹ – millilitres per kilogram per minute
BCAA – branch chain amino acids	mmol·L ⁻¹ – millimoles per litre
BMI – body mass index (kg·m ⁻²)	N/M – not measured
bpm – beats per minute	N/S – no significant differences
CHO – carbohydrates	NEFA – non-esterified fatty acids
CHO ox – rate of carbohydrate oxidation	NKQ – nutritional knowledge questionnaire
CON – placebo meal	NR – not reported
ELISA – enzyme-linked immunosorbent assay	PCr – phosphocreatine
ex – exercise	pp – post-prandial
Fat ox- rate of fat oxidation	R – rest period
FFA – serum free fatty acids	RDA – recommended dietary allowance
g·kg bw ⁻¹ – grams per kilogram body weight	RER – respiratory exchange ratio
g·min ⁻¹ – grams per minute	RPE – rate of perceived exertion
GI – glycemic index	T _{ex} – time to exhaustion
Gluc – glucose	TT – time trial
HGI – high glycemic index	VCO ₂ – carbon dioxide output
I – isocaloric matched meals	Vmax – peak treadmill speed
kcal·g ⁻¹ – kilocalories per gram	VO ₂ – oxygen uptake
kg·m ⁻² – kilograms per meter squared	VO ₂ max – maximal oxygen uptake

CHAPTER 1

INTRODUCTION

Nutrition and diet quality are key components to athletic training and performance. The impact of nutrition on endurance exercise and high intensity, short duration sports has gained specific momentum in recent years [1]. Varying the consumption of carbohydrates (CHO) before exercise affects substrate utilization, hormonal regulation, recovery, perceived exertion, exercise intensity, and fatigue resistance [2]. While controversy exists over the proportions of CHO, protein and fat in the athlete diet, CHO intake has continued to prevail as the most important source of energy for athletes. The primary mechanism for CHO ingestion in improving exercise endurance is through the preservation of muscle glycogen. Strategies to enhance the effects of CHO intake, and sport-specific recommendations are now important topics for research.

Carbohydrates are beneficial to athletes when consumed one to four hours before exercise (pre-exercise), during exercise, and within a half hour after exercise (recovery meals) [3]. Though the timing of carbohydrate intake has clear benefits to athletes, the optimal composition of CHO in the diet continues to be a dynamic and contested area in the literature. Specifically, the influence of carbohydrates types (i.e. the digestive and absorptive characteristics) is poorly understood. Particular interest has been paid to the quality, specifically the glycemic index (GI) [4], of CHO foods and their impact on athletic performance. The research results involving pre-exercise meals of different glycemic indices have been variable, with either enhanced performance [5-9], or no significant differences in performance between different meal GIs [10-16]. Due to the wide range of methodologies employed in these studies, specifically in meal composition and timing and performance measures, consensus on the role of GI in enhancing performance has not been reached.

Soccer (football) is the most popular sport worldwide, with over 265 million players internationally [17, 18]. In Canada, soccer attracts many individuals for competition, physical activity, and camaraderie. Soccer has the third highest participation rate in North America, with approximately 850,000 registered players in Canada, composed of 43 and 57% females and males, respectively [19]. Competitive matches and tournaments are held year-round. Elite competition regionally, nationally and internationally also attracts many players who push the boundaries of their physical capabilities and strive for improvement. The physiological stress coinciding with performance goals result in a number of training barriers that need to be overcome by planning and strategizing to balance training and recovery [20]. Nutrition plays an important role in optimizing this process [21].

Tournament play is an important component of soccer competitions which requires substantial amounts of energy as well as the ability to recover from exercise in time for subsequent games. Nutrition research in athletic performance during these highly demanding events is scarce. Many theoretical frameworks exist that implicate pre-exercise meals in sustaining athletic performance and endurance, including maintenance of blood glucose [22], reduced amino acid oxidation [23], and protection of muscle glycogen [24]. The consumption of low glycemic index (LGI) foods is a viable option for sustained and consistent substrate availability in the blood and metabolism at the cellular level. Lentils contain optimal amounts of macronutrients, and with increased acceptability, the consumption of lentils as a pre-exercise meal would improve quality CHO and protein supply to the athlete. Previous research has found a number of positive results throughout a range of methodologies, but has neglected some key factors including exercise during variable intensity activity and gender differences.

Based on such gaps in the literature, the purpose of the present study is multifaceted. Firstly, the glycemic response, palatability and acceptability of a lentil-based pre-exercise meal containing lentils, honey, and Saskatoon berries was determined prior to a soccer tournament simulation. Secondly, due to the low consumption of lentils and pulses in the Canadian population, a questionnaire validation study was executed to investigate athletes' beliefs and barriers to pulse-based meal consumption. Finally, using

a previously validated, treadmill-simulated soccer protocol, the effects of a lentil-based, LGI pre-exercise meal on metabolism and exercise performance were determined during consecutive soccer matches separated by a three hour break (i.e. to simulate tournament play).

CHAPTER 2

LITERATURE REVIEW

2.1 Nutrition for optimal performance

Diet quality is a pivotal component of an athlete's regime for training and performance. Carbohydrates (CHO) and fat provide the energy needed to execute and maintain exercise for both short and long durations. Protein plays a number of roles during exercise, including the supply of energy and ensuring proper function during exercise, and facilitating recovery after exercise.

2.1.1 Carbohydrates

The suggested intake for CHO throughout the day for soccer players in pre-season is 7 to 10 grams per kg body weight per day ($\text{g}\cdot\text{kg bw}^{-1}\cdot\text{day}^{-1}$) [25]. Within the same context, all athletes should consume 6 to 10 $\text{g}\cdot\text{kg bw}^{-1}\cdot\text{day}^{-1}$ [3]. Recommendations for pre-exercise meals suggest 2.0 $\text{g}\cdot\text{kg bw}^{-1}$, while during exercise athletes should consume 0.7 $\text{g}\cdot\text{kg bw}^{-1}$ per hour [3]. Finally, optimal CHO intake after exercise is 1.0 to 1.5 $\text{g}\cdot\text{kg bw}^{-1}$ within 30 minutes of finishing a workout, and every 2 to 4 hours afterwards [3].

2.1.1.1 Mechanisms for endogenous and exogenous carbohydrate use during soccer

Elite soccer players commonly maintain an intensity of approximately 70% of maximal oxygen consumption (VO_2max) during a match [26]. Such exercise intensities are relatively high, and demand carbohydrates for fast energy provision. Daily carbohydrate intake and pre-exercise carbohydrate intake are thus designed to maintain blood glucose and muscle glycogen during exercise, and replace depleted muscle glycogen stores after exercise. Pre-exercise carbohydrate ingestion improves endurance capacity [27, 28] by increasing pre-exercise glycogen stores and supplemental glucose so glycogen stores can be spared during exercise [29]. Endogenous carbohydrates, in the form of glycogen, are the most important substrate for endurance exercise, including soccer performance [26]. Glycogen depletion is observed in both moderate and high

intensity exercise; of both intermittent and steady-state activity [30, 31]. With 80% of glucose in muscle coming from muscle glycogen [32], and depletion of muscle glycogen between 40 to 90% during a soccer match [33], muscle glycogen depletion is the most likely contributor to performance and fatigue. Glycogen sparing increases resistance to fatigue [33-35]. High initial glycogen stores before the start of a soccer game have not been shown to improve time to exhaustion, but rates of glycogen depletion throughout soccer-specific exercise is associated with time to exhaustion [36]. At the end of a soccer match, muscle glycogen depletion, in addition to dehydration and increased muscle temperature, are the main contributors to fatigue [37]. The rank order of these factors is likely dependent on environmental conditions, nutrition, and hydration.

In addition to its role in reducing glycogen depletion [36], exogenous carbohydrate ingestion prior to a soccer match may improve performance in a number of ways. Pre-exercise CHO intake also helps to maintain better levels of plasma glucose [38], which is a limited source of energy for both working muscles and the central nervous system during exercise [39]. Carbohydrate intake improves performance, central nervous system function, and moods during intermittent running [39]. The benefits of CHO are evident regardless of intake schedule (i.e. in a large bolus or regular small servings) [40]. Moreover, CHO ingestion after exhaustion can extend time to exhaustion upon returning to exercise after a short rest [2].

2.1.1.2 Quality of carbohydrates

The body's use of CHO upon ingestion is a complex process that requires a number of key enzymes and hormones, largely directed by the release of insulin after the increase in plasma glucose during digestion. Carbohydrates are rapidly absorbed in the small intestine, and the influx of glucose to the blood stream stimulates the release of insulin to trigger cellular uptake of carbohydrates. The glycemic response to CHO ingestion is a measurement of the rate at which CHO is stored over a two hour period. First developed in 1980, the glycemic index (GI) of a food is the area under the glycemic response curve in the two hour post-prandial period compared to a bolus of glucose providing the same available carbohydrate content [4]. The resulting value is generally within a range of 5 to 100 [41]. The index allows for comparison and classification

between carbohydrate-rich foods. Three categories, based on respective glycemic index, are: (i) low GI (LGI) foods ($GI \leq 55$), (ii) moderate GI foods ($55 < GI < 70$), and (iii) high GI (HGI) foods ($GI \geq 70$). The glycemic index of a food is largely guided by the type and physical properties of the carbohydrate fraction of the food. Intrinsic factors of amylose and amylopectin content, the size of the starch granules, and physical interactions of carbohydrates with fat and protein all influence digestibility and absorption of carbohydrates. Meanwhile, extrinsic factors include the viscosity of the fibres, presence of enzyme inhibitors, and the degree of food processing.

Current use of GI in nutritional counseling focuses primarily on diabetic and pre-diabetic patients, since blood glucose control via LGI foods is a primary strategy to slow the progression of diabetes. Jenkins et al. [42] found dietary counseling with a focus on reducing GI of the diet reduced cardiovascular risk factors of Type 2 diabetes patients in comparison to whole grain and fibre counseling. Reducing dietary GI by 14 points causes a number of positive changes, including increased fibre intake, lower fasting blood glucose, and higher high density lipoprotein compared to high cereal fibre counseling alone [42]. Such findings are supported by epidemiological research [43, 44]. While smaller regulatory bodies have made recommendations to reduce GI of the diet to prevent chronic disease, the Institute of Medicine [45], responsible for setting the Dietary Reference Intakes, did not set recommendations for the type and quality of carbohydrate consumption in 2005 (its most recent recommendation release) because further evidence of the benefits of GI for healthy populations was needed, and such recommendations require substantial changes in current North American eating patterns [45].

2.1.1.3 Glycemic index in sports nutrition

The use of GI as a quality indicator of carbohydrates has received some interest over the last 20 years for exercise performance. Pre-exercise meals differing in GI may result in improved performance and metabolic response to exercise [5]. HGI foods are absorbed in the intestine and introduced to the blood stream quickly. Increased blood glucose then triggers insulin release from the pancreas prompting increased uptake of glucose by cells to decrease blood glucose. Hepatic and muscle glycogenesis and fatty acid synthesis are elevated due to increased insulin. Rapid post-prandial glucose response

before exercise may lead to decreased carbohydrate availability during exercise. A large increase in insulin release may lower blood glucose concentrations below normal (referred to as “rebound hypoglycemia”), reducing glucose availability at the start of exercise [46]. Mitigating this insulinemic response can be achieved by reducing the GI of pre-exercise foods, where blood insulin levels do not increase much above the pre-meal state.

Rebound hypoglycemia has been observed in early studies investigating pre-exercise meal ingestion but has not been reported in more recent research [47, 48]. It remains to be seen if LGI pre-exercise meals protect against this phenomenon. However, LGI pre-exercise meals protect against glycogenolysis [47, 48] by slowing digestion of the pre-exercise meal and allowing slow release of carbohydrates throughout running, cycling and soccer specific exercise [6, 49, 50]. Large rates of glycogenolysis during exercise increase production of lactic acid and deplete glycogen, both of which may lead to fatigue.

High insulin release before exercise also inhibits lipolysis and fatty acid oxidation in skeletal muscle [46]. Even when insulin returns to baseline at the start of exercise, it still has a long-lasting effect to inhibit fatty acid oxidation and increase carbohydrate oxidation in trained men and women [51, 52]. Reducing the GI of the pre-exercise meal, thus reducing the insulinemic response to the meal would shift substrate utilization to increased fatty acid oxidation, reduce carbohydrate oxidation, and sustain muscle glycogen.

2.1.2 Fat and protein

Fat metabolism also plays a role in soccer-specific exercise although making up a smaller proportion of energy supply to working muscle. Recommended fat intake for athletes is described as an acceptable macronutrient distribution range (AMDR) of 20 to 35% of caloric intake to ensure adequate intake of essential fatty acids and fat soluble vitamins [3]. During lower intensity portions of the game, the dependence on the fast energy systems (i.e phosphocreatine (PCr) and glycolysis) is reduced and oxidative phosphorylation utilizes both glucose and fatty acids for resynthesis of ATP. Fat metabolism also depends on the duration of activity. Fat metabolism increases throughout

a soccer match, while CHO metabolism decreases [53]. Similarly, fat oxidation during exercise may depend on the availability of fat and carbohydrates to the system [54]. Increased fat consumption is generally not recommended because adequate intake is met without intention and body fat stores are considered adequate to supply any fat oxidation during exercise. High fat pre-exercise meals have resulted in decreases in glycogenolysis similar to those seen with LGI pre-exercise meals, but contraindications to high fat diets include increased cardiovascular disease risk [55].

Protein requirements of athletes are a popular area of discussion in sports nutrition research and popular media. The current recommendations for athletes, between 1.2 to 1.4 g·kg bw⁻¹·day⁻¹ [3], is higher than the recommended intake of 0.8 g·kg bw⁻¹·day⁻¹ for the North American population [45]. Recommendations published specifically for soccer players suggest protein intake up to 1.6 g·kg bw⁻¹·day⁻¹ [25]. While few studies have been performed to determine nitrogen balance for moderate to high intensity exercise, such as soccer, there is no evidence to suggest protein requirements for these athletes is higher than 1.6 g·kg bw⁻¹·day⁻¹ [56].

Published data proposed to investigate the actual requirements for athletes has utilized both nitrogen intake/excretion and isotope tracer methods to accurately report protein utilization. Endurance athletes require greater quantities of protein than the regular population to provide amino acids for energy during exercise and cellular repair (anabolism) after exercise [56, 57]. Endurance exercise without sufficient energy supply may also result in the breakdown of muscle to supply amino acids for energy [58]. More specifically, branch chain amino acids (BCAA), such as leucine, can easily enter the Krebs cycle and provide substrate for oxidative phosphorylation during exercise. BCAA breakdown may contribute to central nervous system fatigue [59] and an increased supply of BCAA decreases muscle glycogen degradation during exercise [60]. The addition of protein to pre-exercise carbohydrate meals reduces carbohydrate oxidation, compared to carbohydrates alone, and improves repeat sprint performance at the end of 75-minutes of simulated soccer exercise [61]. Supplying small amounts of protein in addition to CHO during recovery from endurance exercise may reduce muscle damage and improve recovery [62, 63] and glycogen resynthesis [64].

2.1.3 Dietary practices of athletes

Athletes are held as esteemed figures of health and physical fitness. While a growing number of athletes are optimizing their nutrition and lifestyles to complement training and competition, a number of studies report poor dietary status and nutritional knowledge, increased prevalence of eating disorders [65], overuse of supplements, and a variety of health-related risk taking behaviours [66] among competitive athletes.

The dietary practices of athletes are generally similar to non-athletes. Varsity athletes are not more likely to consume fruits and vegetables, and equally likely to over-consume meat products in comparison to non-athletic college students [67]. Varsity athletes in a National Collegiate Athletic Association Division I University in the United States have been reported to consume very low daily intakes of carbohydrates; approximately 3.6 and 4.6 g·kg bw⁻¹·day⁻¹ for males and females, respectively [68]. In a comprehensive review of dietary studies published between 1971 and 1997, Burke et al. [69] reported male and female athletes' CHO intake. No significant difference between CHO intake was observed when comparing studies between 1971 and 1989 (7.3 and 5.4 g·kg bw⁻¹·day⁻¹, respectively for males and females, respectively) and between 1991 and 1997 (7.6 and 5.7 g·kg bw⁻¹·day⁻¹) [69]. Carbohydrate intake was dependent on the type of sport. For instance, middle distance runners consume 5.5 g·kg bw⁻¹·day⁻¹ and cross-country skiers consume 14.6 g·kg bw⁻¹·day⁻¹ [69]. While research has continued to report the importance of CHO ingestion for performance, the translation and dissemination of such information is apparently deficient.

Poor dietary behaviours among athletes are generally associated with aesthetic or weight category sports rather than with other endurance sports or team sports. In British male soccer players, mean carbohydrate intake was 4.8 g·kg bw⁻¹·day⁻¹ [70]; below the recommendations for soccer players (7 to 10 g·kg bw⁻¹·day⁻¹) and endurance athletes (6 to 10 g·kg bw⁻¹·day⁻¹) [3, 25]. Male club soccer players aged 14 to 21 consumed low quantities of carbohydrates (5.4 g·kg bw⁻¹·day⁻¹) and fibre (less than 50% of the Recommended Dietary Allowance (RDA)), and high amounts of fat (38% of calories) [71]. Female elite soccer players have CHO intake of 4.7 g·kg bw⁻¹·day⁻¹, below the recommended intake for athletes [72]. Athletes may experience social pressures to appear

athletic and lack the necessary skills, knowledge, and support to implement changes to meet dietary recommendations [73].

Athletes are also predisposed to deficiency in some key nutrients, including iron, vitamin E, vitamin B12 and magnesium [3]. While increases in food intake are proposed to assist in meeting increased needs for all micronutrients, the under-consumption of nutrients is still prevalent. In female soccer players, dietary intake of zinc, magnesium, calcium, vitamin E, and folate are often below the RDA for these nutrients [72]. Over the long term, low intakes of nutrients in athletes can lead to anemia, osteoporosis, and injury [74, 75]. With this information in mind, it is not only important to counsel athletes to reach short-term optimal nutrition for competition, but also include recommendations to achieve long-term quality of life and health.

Dietary supplementation is commonly used to correct for poor dietary habits. Athletes of all ages and levels have reported using dietary supplements during training. College athletes consume nutritional supplements based on recommendations from training staff and family members rather than dietitians, physicians and pharmacists [76, 77]. Dietary supplementation is common in Canadian athletes, many of whom consume sports drinks, sports bars, and protein supplements [78]. A primary concern in supplement use, especially at the elite level, should be the purity of such dietary supplements, but both junior and senior athletes have shown little concern for this issue [79].

The main barriers to proper diet for athletes are time management, finances, lifestyle, physique, and a lack of nutrition and food preparation knowledge [73]. Attitudes towards nutrition are generally positive in athletes but nutritional knowledge is lacking [80]. Athletes know carbohydrate ingestion is a major contributor to performance, but as many as half of athletes believe protein is the main energy source for muscle (false) and that vitamins and minerals boost energy levels (misinformation) [81]. Nutritional knowledge education, practical skills in food preparation and time management strategies should be included as part of athlete counseling.

1.1.3.1 Pulses for performance

Pulses, also referred to as legumes, are seeds of plants. These include beans (kidney beans, white beans, black beans, navy beans), soy beans, chickpeas, peas (i.e split peas), and lentils (red, yellow, and green). Pulses are generally composed of carbohydrates, protein and fibre. Due to the large starch particle size and a high ratio of amylose-to-amylopectin content, pulses have slower digestion rates than other dietary carbohydrates such as wheat or root vegetables. Inclusion of these foods into the diet may be beneficial because of both their low GI and their supply of high-quality protein [82].

Lentils (*Lens culinaris*) are composed of 65% CHO, 28% protein, 1% fat, and 6% crude fibre and ash [83]. The CHO fraction in lentil consists of about 53% starches and oligofructosaccharides, 40% fibre and 7% sugars. Approximately 19% of the protein in lentils is composed of branch chain amino acids (BCAA) [84]. Overall, the GI of lentils is low, between 27 and 30 [41]. A serving of lentils (175 mL) provides 22% of the RDA for iron, 23% of the RDA for potassium, and 25% of the RDA for folate. Thus, lentils represent a nutrient-dense carbohydrate and protein source for the diet.

In addition to nutrient quality, legumes contain a number of bioactive non-nutritive compounds that positively influence human health. Of these, enzyme inhibitors, lectins, phytates, and saponins have been identified to influence mechanisms of colorectal disease, diabetes, and certain cancers [85, 86]. Legumes also contain a number of phenols, including simple phenols, tannins and flavanoids [87]. These components contribute to the antioxidant capacity of human cells, and defend against reactive oxygen species and oxidative stress. Antioxidant compounds, soluble fibre, vegetable protein, oligosaccharides, and phospholipids, have shown hypocholesterolemic effects, and thus reduce risk of cardiovascular disease, diabetes, and cancer [88, 89].

Canada is the largest producer of peas and lentils, and is one of the top five producers of pulses in the world [90]. Though Canada is the largest producer, the majority of yields are exported to other countries with higher levels of per capita lentil consumption [91]. These countries include Algeria, Bangladesh, and Belgium. With Canadians exhibiting a growing preference for consuming locally-produced foods, pulses are conceivably the most neglected Canadian-produced crop with the greatest potential to

improve health. The specific effects of these foods for athletes should be evaluated, as athletes are at equal risk for poor dietary habits as many other groups, but their nutrient demands are higher, putting them at increased risk for deficiency.

1.1.3.2 Questionnaires to evaluate beliefs and barriers to pulse consumption

No previous research is available on the factors associated with pulse consumption. Identification of factors associated with diet and health related behaviour is an important first step to developing strategies to improve public consumption of these high quality foods. Conceptualization of dietary behaviours is a complex area of psychology and nutrition. A number of motivational models exist to predict behaviour, including the health belief model [92], and the diffusion of innovations model [93].

The health beliefs model suggests when an individual's perceived beliefs outweigh perceived barriers towards health behaviour; an individual will choose to execute that behaviour [92]. This model has been shown to predict behaviour in a number of instances [94, 95]. Health status and health-related behaviours are strongly associated with healthy food choices and fruit and vegetable intake in adults [96]. Furthermore, identification of beliefs and barriers specific to athletes may also be valuable as tailored information and programs have been effective previously in specialized populations [97]. The diffusion of innovations model is similar, where the benefits to change behaviour to include new innovations must outweigh the benefits of current practices. The diffusion of innovations model can be insightful when studying healthy individuals between the ages of 18 and 24 years because the benefits of implementing new behaviours may not overcome the benefits of health this population already exhibits [98].

Using the health beliefs model, Lea et al. [99] utilized focus groups to develop a valid questionnaire addressing the main factors associated with a plant-based diet (an eating pattern dominated by fresh or minimally processed plant foods and decreased consumption of meats, eggs, and dairy products). The resulting questionnaire identified key practical and attitudinal barriers. Results agreed with previous research, finding practical barriers, such as a lack of information about plant-based diets, limited time to prepare meals and a lack of food preparation knowledge, and attitudinal barriers like the belief that one's diet is already healthy [99-101]. Respondents also agreed with belief

statements addressing the nutrient quality of plant-based diets, such as decreasing one's saturated fat intake [100]. As pulse-based meals fall within a plant-based eating pattern, this questionnaire was deemed an appropriate starting point to determine beliefs and barriers to pulse-based diets [100].

Important co-factors should also be evaluated when determining the beliefs and barriers towards health behaviour. Nutritional knowledge is a key factor in dietary practices [102] and the main assumption of nutrition education strategies is the translation of knowledge into action and practice [103]. Attitudes towards health and nutrition are also positively associated with dietary practices [104]. Zawila et al. [80] previously administered and validated a nutritional knowledge questionnaire (NKQ), adjusted from Barr [105] and Werblow et al. [106], to female collegiate cross-country athletes. The NKQ was comprised of 76 Likert-scale true-false questions including 17 athlete-specific nutrition questions and 59 general questions with subsections questioning knowledge of macronutrients, micronutrients, hydration, diet-related health outcomes, and eleven questions regarding attitudes towards healthy eating for athletes. Likert-scale questions have pre-set responses on a continuum (i.e. strongly disagree, disagree, neither agree or disagree, agree, and strongly agree) resulting in interval data to evaluate attitudes [107]. Sufficient evidence exists to apply this NKQ to accurately appraise the nutritional knowledge of athletes and how such knowledge may correlate to beliefs and barriers towards pulse-based meal consumption.

Non-modifiable socio-demographic factors are also strong predictors of dietary behaviour [108]. Cultural influences on dietary behaviours are a significant component of pulse consumption, as Middle Eastern, South Asian, and African populations consume more pulses and legumes than in the Western world [109]. Gender, age, income, education level, household demographics, and health conscious behaviours are all associated with dietary intake and therefore likely influence pulse consumption as well [100, 110-112].

Based on the available previous literature, a preliminary questionnaire investigating the beliefs and barriers towards pulse-based meals can be developed using diet-related beliefs and barriers, nutritional knowledge, health attitudes, and

sociodemographic factors. The results from this questionnaire would serve as a novel contribution to scientific literature in the area of pulse research and dietary behaviour modification.

2.2 Energetics of soccer match play

Competitive soccer requires a balance between endurance and sprinting ability, technical skill and agility. On average, adult elite midfield soccer players cover 8 to 12 kilometers in one game through multiple high-intensity intermittent sprints punctuated by low- and moderate-intensity walking and jogging [20, 26]. Motion analysis during match play shows standing, walking, jogging, running and sprinting activity represents 7, 56, 30, 4, and 3% of the time during a match, respectively [113]. Such a wide range of intensities requires a high metabolic demand to fuel ATP resynthesis throughout a match.

2.2.1 Metabolism in repeated sprints

With a wide range of intensity and interval work on a soccer field, players require both anaerobic and aerobic systems to meet the energy needs of working muscles. The intensity and frequency of running and sprinting require energy supplied by high energy phosphate compounds of adenosine triphosphate (ATP) and phosphocreatine (PCr) in anaerobic metabolism. Anaerobic glycolysis can be used to supply energy in a number of scenarios in a soccer match to provide immediate ATP: (i) when sprints last longer than ten seconds, (ii) when multiple short duration sprints are performed without adequate recovery time, and (iii) before adequate oxygen is available at the cell. Intermittent sprinting with active recovery (walking or jogging) requires PCr and glycolysis for immediate supply of energy to sprint, and oxidative phosphorylation to provide energy necessary to re-phosphorylate creatine and clear accumulated metabolites from muscle and blood during recovery segments [114, 115]. As soccer players perform repeated sprints amongst a wide range of skill and strategic movements, they require oxidative phosphorylation to sustain continual performance and short-term recovery.

With different energy systems at work, the demand for substrates is variable. Carbohydrate oxidation is primarily used to meet urgent energy demands when running and sprinting, while fat oxidation, a slower process, can easily meet energy demands during walking and jogging. Carbohydrates for working muscle are found in muscle

glycogen and blood glucose, while intramuscular fat and serum fatty acids act as substrate for fatty acid metabolism.

2.2.3 Fatigue in soccer

Training and athletic development does not preclude athletes from fatigue, but rather improves the speed and power, and potentially time before symptoms of fatigue appear. Fatigue, or the “failure to maintain the required or expected power output” [116], continues to be evaluated in the scientific literature [117]. Fatigue during a soccer match may be due to a number of peripheral mechanisms including the production of lactic acid, hydrogen ions, and phosphate, alterations in calcium release and loss of potassium from muscle [117]. Near the end of a soccer match, players are more likely to experience fatigue due to decreases in muscle glycogen, and increasing levels of dehydration and increased muscle temperatures [20]. Fatigue in soccer also manifests through decreased technical performance and ball handling skills [118].

2.3 Gender differences in exercise metabolism

The majority of performance studies examining the influence of pre-exercise meal GI have used primarily male subjects. Male subjects are more common because they are more likely than females to participate in competitive sports and to participate at higher levels of competition [119]. Researchers may also place more stringent inclusion criteria on female participants due to variable substrate oxidation throughout the menstrual cycle or perturbations in the menstrual cycle due to intense exercise programs [120, 121].

Males and females exhibit a number of metabolic differences during exercise. Females have a lower respiratory exchange ratio (RER) than males, potentially due to higher estrogen levels which reduce carbohydrate oxidation and increase fat oxidation [120]. During the menstrual cycle, glycogen utilization is depressed during the luteal phase compared to the follicular phase [122]. Anthropometrically, females have higher percentage fat mass and intramuscular fat content while males have higher percentages of lean body mass. Females also experience metabolic changes throughout the menstrual cycle. Such changes do not significantly alter carbohydrate utilization or performance during exercise, but may influence muscle glycogen synthesis [123, 124]. Any metabolic differences observed throughout the menstrual cycle, however, are dominated by

differences between genders [122]. Of particular importance in this instance, the metabolic response to carbohydrate ingestion during exercise is not significantly different between men and women [125].

2.4 The glycemic index and exercise

Some studies have found significantly improved performance with LGI compared to HGI pre-exercise meals [5-9], while others have reported no significant differences in performance between meal types [10-16]. No studies have found reduced performance after consuming a LGI meal in comparison to a HGI pre-exercise meal (**Table 1.1**).

Exercise modalities have varied within the previous literature. Cycling has been the primary exercise used to assess pre-exercise GI foods and performance [5, 7-13, 15, 16], while three studies have used steady-state running as an exercise mode [6, 9, 14]. These studies have either a cycle or run to exhaustion [5, 7-10, 16], a steady-state ride followed by a performance ride of some pre-determined output (i.e. time to complete 300 watts or 30 minutes at maximal volitional speed) [11-13, 15]. Running studies have more commonly used time-trial performance criteria [6, 9, 14]. Results from these studies have been positive, where LGI trials have either resulted in significantly longer time to exhaustion [9], or decreased time to complete a 21-km run [6]. Wee and colleagues [14] reported a sparing effect on muscle glycogen utilization during a steady-state 30-minute run after LGI meal consumption [14]. LGI meals have a positive effect on metabolism and possibly performance during steady-state running exercise.

LGI pre-exercise meals result in lower post-prandial glucose and insulin response compared to HGI trials [5, 6, 8-15], as would be expected based on the theories of Jenkins et al. [4]. During exercise, the plasma glucose content is also higher in the LGI trials at the beginning of exercise and showed no significant differences later on in exercise [5, 6, 9-11, 13], or the same as the HGI trial throughout the trial [12].

Conversely, plasma free fatty acid concentrations ([FFA]) during exercise after a LGI meal are elevated compared to the HGI meal [5, 6, 9, 13, 15, 126]. Non-significant differences in [FFA] occur during steady-state, fixed time trials at a fixed intensity [10, 12] or during an exhaustive trial [7, 14]. On six occasions, lower CHO oxidation rates

Table 2.1: Studies evaluating difference in metabolism and performance after consuming low glycemic index and high glycemic index pre-exercise meals.

Study	Subjects (VO _{2max} mL ·kg ⁻¹ ·min ⁻¹)	Meal conditions (GI, respectively)	CHO Content (g·kg ⁻¹)	PP period	Exercise Test	Outcomes	
						Metabolic ^a	Performance ^a
Thomas et al.(1991) [5]	8 ♂ cyclists (55.6 ± 5.4)	Glucose, potato, lentil, CON (100, 98, 29)	1.0	60 min	Cycle T _{ex} @ 65-70% VO _{2max}	↓ pp gluc, ↓ lactate, ↓ RER, ↓ CHO ox, ↑ [FFA]	↑ T _{ex} : 117 ± 11 min for LGI vs. 97 ± 11 min for HGI
Thomas et al. (1994) [10]	6 ♂ cyclists (59.7 ± 7.3)	Potato, rice, lentil, bran (100, 73, 36, 30)	1.0	60 min	Cycle T _{ex} @ 65-70% VO _{2max}	↓pp gluc, ↑ ex. gluc, ↑ [FFA], ↓ insulin, ↓ RER	N/S
Febbraio et al. (1996) [11]	6 ♂ cyclists (62.1 ± 3.6)	Potato, lentils (80, 29)	1.0	45 min	Cycle 120 min @ 70% VO _{2max} + 60 min R + 15 min TT	↓ pp gluc, ↓ pp. insulin, ↑ FFA, ↓ RER	N/S
Burke et al. (1998) [12]	6 ♂ cyclists (68.6 ± 3.8)	Potato, pasta, CON (87, 37); I (+ 2.4 g·kg ⁻¹ during ex.)	2.0	120 min	Cycle 120 min @ 70% VO _{2max} + 300 kJ TT	↓ pp gluc, ↓ insulin	N/S
Sparks et al. (1998) [13]	8 ♂ triathletes (67.9 ± 2.8)	Potato, lentils (80, 29)	1.0	60 min	Cycle 50 min @67% VO _{2max} + 15 min TT	↓ pp gluc, ↓ pp insulin, ↓ RER, ↓ CHO ox, ↑ Fat ox.	N/S
Demarco et al. (1999) [8]	10 ♂ cyclists (61.8±5.2)	Mixed breakfasts (69, 36)	1.5	30 min	Cycle 120 min @ 70% VO _{2max} + 100% T _{ex}	↑ pp gluc, ↑ T _{ex} gluc, ↓ pp insulin, ↓ RER, ↓ RPE, ↑ T _{ex} VO _{2max} .	↑ T _{ex} : 206 ± 43 min for LGI vs. 130 ± 23 min for HGI

Table 2.1 continued

Wee et al. (1999) [14]	8 ♂, 3 ♀ runners (51.9 ± 1.5, 44.7 ± 1.0)	Potato, lentils (NR)	2.0	180 min	Run T _{ex} @ 70% VO _{2max}	↓ pp gluc, ↓ pp insulin, ↓ pp lactate, ↓ RER, ↓ CHO ox, ↑ Fat ox.	N/S
Febbraio et al. (2000) [15]	8 ♂ athletes (60.5 ± 5.0)	Potato, muesli, CON (80,52)	1.0	60 min	120 min @ 70% VO _{2max} + 30 min TT	↓ pp gluc, ↑ ex gluc, ↓ pp insulin, ↑ FFA, ↓ CHO ox, ↑ Fat ox	N/S
Wee et al. (2005) [126]	7 ♂ runners (55.1 ± 2.3)	Mixed breakfasts (80, 36); I	2.5	180 min	Run 30 min @ 70% VO _{2max}	↓ pp gluc, ↓ pp insulin, ↓ ex. lactate, ↓ RER, ↓ CHO ox, ↑ FFA, ↑ Fat ox	N/M
Wu et al. (2006) [9]	8 ♂ runners (60.6 ± 1.5)	Mixed breakfasts (77,37); I	2.0	180 min	Run T _{ex} @ 70% VO _{2max}	↓ pp gluc, ↑ ex gluc, ↓ pp insulin, ↑ pp lactate, ↑ FFA, ↓ RER, ↓ CHO ox, ↑ Fat ox	↑ T _{ex} : 109 ± 4 min for LGI vs. 101 ± 5 min for HGI
Wong et al. (2008) [6]	8 ♂ runners (61.0 ± 1.8)	Potato, pasta (77,37); I	1.5	120 min	Run 21-km TT	↓ pp gluc, ↑ ex. gluc, ↓ pp insulin, ↓ RER, ↓ CHO ox	↓ TT: 99 ± 2 min with LGI vs. 102 ± 2 min for HGI
Moore et al. (2009) [49]	10 ♂ cyclists (58.2 ± 10.1)	Mixed breakfasts (72, 30)	1.0	45 min	Cycle 40-km TT	↓ pp gluc, ↓ pp insulin , ↑ CHO ox, ↓ Fat ox, ↓ RPE	↓ TT -93 ± 8 min with LGI vs. 96 ± 7 min for HGI
Little et al. (2009) [61]	7 ♂ soccer players (57)	Potato, Lentil (81, 29)	1.3	180	75 min simulated soccer game + 5 repeated 1-min sprint intervals	↓ pp gluc, ↓ pp insulin ↓ RPE	N/S

Table 2.1 continued

Soccer Tournament Studies						
Stevenson et al. (2005) [127]	9 ♂ soccer players (61.0 ± 5.7)	Recovery mixed meals, (70, 35)	8.0	22 hrs	90 min LIST SR @ 70% VO _{2max} + 22 hr R + T _{ex} @ 70%	↑ FFA, ↓ RER, ↑ Fat ox, ↓ RPE ↑ T _{ex} : 108.9 ± 7.5 min for LGI vs. 96.9 ± 4.8 min for HGI
Erith et al. (2006) [128]	7 ♂ soccer players (58 ± 0.8)	Recovery mixed meals, (70, 35); I	8.0	22 hrs	90 min LIST SR @ 70% + 22hr R + 75 min LIST SR + Sprint/Jog T _{ex}	N/S N/S

VO_{2max} – maximal oxygen uptake; NR – not reported; CON – placebo meal; I – isocaloric matched meals; T_{ex} – time to exhaustion; TT – time trial; R – rest period; LIST SR – Loughborough Intermittent Shuttle Test Shuttle Run; ↑ – increased; ↓ – decreased; pp – post-prandial; ex – exercise; Gluc – glucose; FFA – serum free fatty acids; RER – respiratory exchange ratio; CHO ox – rate of carbohydrate oxidation; Fat ox – rate of fat oxidation; RPE – rate of perceived exertion; ^a outcomes where p<0.05 for LGI compared to HGI only. N/M- not measured; N/S- no significant differences reported between trials.

were reported in the LGI trials compared to the HGI trials [5, 6, 9, 13-15] and not significantly different on two occasions [11, 12]. Fat oxidation is less commonly reported in the literature, but is typically increased in LGI trials compared to HGI trials [6, 9, 11, 14, 15]. Respiratory exchange ratios have also been lower in the LGI trials compared to the HGI trials, reflecting higher fat than CHO oxidation [5, 6, 8-10, 13].

Muscle glycogen data have been reported on two separate occasions in the literature. Febbraio et al. [15] found glycogen content was not significantly different between the HGI, LGI and control trials after a 120-minute cycle at 70% VO_2max . Conversely, Wee et al. [126] reported a greater accretion and proportional depletion of glycogen after the HGI pre-exercise meal delivered three hours before a 30-minute treadmill run at 71% VO_2max . The results of both studies showed no significant difference in glycogen utilization between HGI and LGI trials, suggesting the effect of LGI meals on muscle glycogenesis and glycogenolysis is either negligible or unresolved [20].

In summary, the general metabolic outcomes from LGI meals have corresponded to reduced insulin responses leading to increased fat oxidation and decreases in carbohydrate oxidation. The shift in substrate use corresponds to decreased reliance on muscle glycogen stores during exercise.

2.4.1 Simulated soccer matches

Specific research protocols investigating soccer performance after consumption of pre-exercise meals of different glycemic indices has received little attention in the literature. One reason may be due to the methodological limitations of measuring soccer performance during match play. The dynamics of match play involve head-to-head competition, team work, strategy, ball-handling skills, and a wide range of movements along and across the field [129]. These challenges require researchers' creativity to integrate both internal and external validity [130]. Three main methodologies have been used in soccer research, (a) field play while integrating measurements [131], (b) shuttle running protocols [132], or (c) treadmill-simulated match play [133, 134]. Analysis of live soccer match play offers external validity as motion is multi-directional and head-to-head competition can elicit greater motivation in players than lab-based simulations, but

due to the nature of competition, repeatability is impossible and metabolic measurement can be difficult to obtain [130]. The accuracy of these field-based studies cannot be insured without the ability to duplicate the study protocol. Shuttle running protocols offer some balance between lab-based and field-based research, where the subjects run at different intensities between two lines for a given period of time, often five to six 15-minute intervals [132]. This method may have a wide range of variability, but has been validated to distinguish different levels of player experience and different field positions [130]. Recently, the employment of an intermittent intensity (speed) protocol on a treadmill has improved the validity of results from soccer research [130].

Treadmill-based soccer simulations utilize information from motion analysis to determine the amount of time a player spends at different intensities, and then transcribes those times and intervals into treadmill speeds. Simulated treadmill protocols provide ample opportunity for repeatability of exercise intensity, lab measurements, including gas collection and blood samples, and controlled environmental conditions, such as temperature and humidity [133]. One notable limitation of all research-based evaluations is that many movements, aside from crude locomotion (i.e. forward movement), are not distinguishable with each method [20]. Treadmill-simulated soccer matches are limited as they are unidirectional, and do not account for strategic movements by players.

Previous work at the University of Saskatchewan [50, 61] has determined the effect of LGI and HGI pre-exercise meals on intermittent high-intensity activity using a treadmill-simulated soccer match. The LGI and HGI diets resulted in significant differences between treatments, with the LGI treatment showing improved maximal sprints after a 75-minute soccer simulation [50, 61]. With the development of an intermittent speed protocol that has already been executed, as well as a controlled, reproducible scenario would allow for comparison of different meal conditions, a treadmill-simulated match protocol is the most suitable methodology to evaluate the effect of meals on soccer performance compared to field-based or shuttle running protocols.

2.4.2 Tournament play and pre-exercise meals

Unique aspects of team sports revolve around tournament play. Limited information is available in the scientific literature regarding the physiological demands placed on soccer players throughout tournament play. Reilly [20] reviewed literature regarding the energetics of soccer, as an example of high-intensity exercise, finding ‘extreme energy expenditure’ when players are required to play extra time in a tournament. With regards to residual fatigue from multiple games, time motion analysis of field hockey players over three games showed an increase in walking and standing and fewer sprints in the second and third games played over a four day tournament [114]. Diets to optimize recovery in multi-day events have been developed from a variety of sources but have relied heavily on the available data from regular training.

Other research has investigated the impacts of consecutive games or matches on a variety of outcomes. Bishop et al. [135] evaluated CHO versus placebo loading leading up to two 90-minute bouts of running exercise separated by three days recovery. CHO loading resulted in improved "prolonged strenuous activity performance" but not "short duration activity performance". Hydration [136], cardiac function [137], and rates of injury [140] have been investigated during tournament play, but have not focused on CHO utilization throughout competition. Simulated tournament studies and recovery studies have also utilized a variety of rest periods between bouts of exercise; ranging from 4 hours up to three days.

Two studies have investigated recovery from high-intensity shuttle running using HGI and LGI diets and performance during a second bout of exercise [127, 128]. Stevenson et al. [127] investigated the effects of CHOs of differing GIs on recovery after running for 90-minutes at 70% VO_2max . Twenty-two hours later, after consuming an HGI or LGI diet, subjects completed a run to exhaustion at 70% VO_2max . A longer time to exhaustion was found for subjects consuming an LGI recovery diet. Erith et al. [128] performed a similar meal intervention using a 90-minute intermittent shuttle run protocol to simulate soccer play followed by a 22-hour recovery with HGI or LGI diet and subsequent 75-minute shuttle run followed by sprinting and jogging to voluntary fatigue, but found no significant difference between HGI and LGI groups. The study also

performed interventions looking at LGI and HGI evening meals followed by a HGI breakfast and 60-minute run at 65% $\text{VO}_{2\text{max}}$ the next morning [128]. The HGI and LGI evening meals resulted in significant differences in insulinemic and glycemic response to the HGI breakfast meal, with no differences in metabolic or performance responses in the exercise trial.

Metabolic responses are only one component of performance. Psychological aspects, such as perceived exertion or performance during a match, are also an important component of performance [139]. Previously, significant decreases in soccer players' RPE have been reported with LGI meals, suggesting they may perform better during a second match [61]. No studies have investigated the effects of pre-exercise meals on two consecutive soccer matches in one day.

2.4.3 Strengths and limitations of the previous research

Previous research has shown consistent differences in glycemic and insulinemic response after consumption of diverse GI meals. The responses during exercise have varied to some extent, where researchers have described different levels of glucose and glycogen (when measured) at the end of exercise. These inconsistencies may be due to differences in diet composition, where macronutrient composition of pre-exercise meals was not accounted for adequately [5, 10, 11, 13, 15].

Performance measurements are also widespread in the current research. Time to exhaustion is a good measure of endurance capacity, but does not resemble realistic competition scenarios, and thus tends to be less reliable than time trial methods [82]. The most commonly used type of exercise in the literature is cycling, perhaps for ease of data collection from subjects on a stable platform. Cycling has a unique metabolic demand on individuals and therefore may be limited in application to other endurance performances, such as running or field sports [140]. Respiratory exchange ratio and CHO utilization are significantly lower during running than for cycling (at 55, 65, and 75% $\text{VO}_{2\text{max}}$ during 30-minute intervals) in highly trained men and women [141]. These exercise sessions generally range between 30 to 120 minutes, but no studies have tested the effects of LGI and HGI pre-exercise meals on multiple events in a single day.

No information is available regarding the influence of gender differences on HGI and LGI pre-exercise meal consumption. Most of the research available only includes male subjects, for reasons aforementioned (see section 2.3). The impact of HGI and LGI diets on female athletes is difficult to extrapolate from male athletes because women exhibit different substrate utilization patterns than men [142, 143]. Female athletes, including soccer players, tend to have lower than expected energy and CHO intake based on the predicted energy expenditure equations. Thus, females generally do not consume recommended percentages of CHOs, protein, and fat for active individuals [72, 144].

Finally, Little et al. [61] validated and used a treadmill to simulate soccer specific, intermittent high-intensity exercise to determine the effects of LGI versus HGI pre-exercise meals. This research found improved sprint time after a 75-minute soccer simulation as well as reduced RPE during the LGI trials. These positive effects of the LGI meal will most likely influence athletes later in the day, or during consecutive exercise, when the altered insulinemic response to meals and storage of muscle glycogen may be different after the consumption of a LGI breakfast.

To summarize, three main gaps can be found in the current literature regarding pre-exercise meals of different GIs: (i) There is insufficient information regarding intermittent, high intensity sports which physiologically depend on CHO for energy more than steady-state exercise. (ii) There is little information on the effects of a LGI, high protein pre-exercise meal on fatigue throughout a tournament-style competition. Finally, (iii) insight is lacking into the influence of gender on the response to pre-exercise meals of different GIs.

2.5 Summary

High intensity, intermittent exercise requires a balance of carbohydrate, protein and fat metabolism. Dietary consumption of carbohydrates and utilization of stored carbohydrates are important factors in fatigue resistance. The GI of carbohydrates may play an important role in optimizing energy supply for athletes. LGI may allow for a slower, more continuous release of fuel and thereby improve fat availability and oxidation over a HGI diet. Furthermore, athletes can benefit from healthy dietary changes including whole foods, such as pulses and legumes, as these are comprised of a

complementary mix of carbohydrates and protein to meet their energy needs. Specific challenges exist when exercise is extended beyond a single 90-minute match, such as in tournament settings. Information on the physical demands of tournament play has not been sufficiently evaluated in the literature, not to mention a lack of information on the nutritional demands of such scenarios. This study aims to determine a number of factors relating to GI pre-exercise meals for tournament performance, and the potential metabolic and performance outcomes of such strategies.

2.6 Statement of the problem

The primary aim of this study is to determine the influence of pre-exercise lentil consumption on prolonged intermittent activity common in tournament type sports (i.e. field hockey, rugby, soccer etc.). A secondary aim of this study was determine the underlying factors associated with pulse consumption, or a lack thereof, as these factors are not defined in the literature. Thus the purpose of the present study is multifaceted. Prior to a soccer tournament simulation, the glycemic response, palatability and acceptability of a lentil-based pre-exercise meal (containing lentils, honey, and Saskatoon berries) was determined. Following this, a previously validated, treadmill-simulated soccer protocol was used to determine the effects of a lentil-based, LGI pre-exercise meal on metabolism and exercise performance during consecutive soccer matches separated by a three hour break (i.e. to simulate tournament play). Finally, a questionnaire based on research investigating plant-based diet consumption [100] was developed and administered in parallel with the primary performance study to create a tool for further investigation into the complex constructs of food choices related to pulse consumption.

2.7 Objectives and hypotheses

Objective 1: To investigate the effect of GI on athlete performance during two simulated consecutive soccer matches separated by three hours (i.e. a simulation of tournament play during a single day). The LGI pre-exercise test meal is expected to: (i) decrease respiratory exchange ratio, (ii) decrease carbohydrate oxidation rate, (iii) increase fat oxidation rate, (iv) maintain higher blood glucose levels later in the tournament, and (v) increase free fatty acid levels in comparison to the HGI pre-exercise meal. Based on such metabolic changes, the LGI pre-exercise meal is expected to result in improved

performance (as measured by distance travelled in performance testing) in comparison to the HGI pre-exercise meal.

Objective 2: To evaluate the gastrointestinal symptoms experienced by subjects throughout both HGI and LGI meals using a previously validated rating scale. It is hypothesized that subjects will experience no adverse symptoms after consumption of the LGI meal compared the HGI meal based on its optimized composition following the findings of the pilot project.

Objective 3: To evaluate metabolic differences between males and females in response to both the HGI and LGI pre-exercise test meals. We hypothesize that female subjects will show higher fat oxidation rates than male subjects during both the HGI and LGI trials.

Objective 4: To adapt and validate an existing beliefs and barriers questionnaire [100], which focuses on plant-based diets, for pulse-based pre-exercise meals. The questionnaire will address the beliefs and barriers of pulse consumption and is intended to determine subjects' potential inclusion of pulses in their diet in the future. This questionnaire will be delivered concurrently with demographic and nutritional knowledge questionnaires to determine any confounding and corollary variables such as non-modifiable characteristics in pulse consumption.

CHAPTER 3

RESEARCH METHODS

3.1 Study design

This study was designed in three parts. The major aim of the study was to determine the metabolic and performance markers in the simulated soccer match. In order to administer the lentil-based, LGI meal to a Canadian population, additional ingredients commonly found in Canadian diets were added to improve familiarity to the foods while maintaining a GI of less than 55 units. A pilot study was used to develop the test meal conditions for the principle investigation. **Appendix 3** contains a detailed report of the methodology, results, and discussion of the pilot study. In a second arm of the study a questionnaire was developed and administered to validate a questionnaire aimed at determining athletes' beliefs and barriers to pulse-based meal consumption.

Finally, the principle investigation carried forward as a single-blind, randomized, and counterbalanced cross-over design to determine outcomes of soccer tournament performance after consumption of the newly developed LGI meal compared to a HGI control meal of mashed potatoes and white bread.

3.2 Participants

Participants were recruited using posters distributed around the University of Saskatchewan Campus, Saskatoon community soccer and field sports centres. Thirteen male and nine female participants were initially recruited to participate in the study. Subjects were included in the study based on: (a) negative responses to all of the items in the physical activity readiness questionnaire (PAR-Q, **Appendix 2**), (b) participation in competitive soccer or cardiovascular training involving intermittent intensities (i.e. running) within the last two years, (c) athletic ability to perform two consecutive soccer matches separated by a three-hour break, identified as a minimum relative $\text{VO}_{2\text{max}}$ of $45 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and $50 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for females and males, respectively. Finally, subjects were required to be (d) healthy, non-diabetic, with a normo-insulinemic response to CHO

and exercise. Of those recruited, five participants (four females, one male) were unable to complete the testing due to previous injuries exacerbated during the study. One female withdrew from the study after extensive fatigue during the treadmill familiarization trial. Finally, two males withdrew from the study after severe leg muscle cramping during testing. Thus, ten male and four female participants completed the study. **Table 3.1** is a full description of participant demographics and physical statistics. The data collection period began in May, 2008 and finished in November, 2008. The study procedure was approved by the University of Saskatchewan Biomedical Research Ethics Board (Bio # 08-77, **Appendix 1**). Written, fully informed consent was obtained from all subjects prior to participation (**Appendix 2**).

Additionally, a total of 37 individuals responded to the questionnaire. Of those respondents, ten were participants in the pilot study (**Appendix 3**), 17 were participants in the principle investigation, and 12 were males who were participants in a related soccer trial in 2007 [50].

3.4 Experimental design

3.4.1 Preliminary testing and dietary controls

Preliminary testing included an incremental speed treadmill run to determine maximal oxygen uptake (VO_{2max}) and maximal velocity (V_{max}), on a treadmill (Vacu Med, Model 13622, Ventura, CA), using methodologies described by Harling and colleagues [145], at least one week prior to the first trial day [147]. Participants executed at 5 minute warm-up followed by 3 minutes of stretching. Subjects were then fitted with a mouthpiece connected to a metabolic cart and began running at $10 \text{ km}\cdot\text{hr}^{-1}$. The treadmill was programmed to increase speed by one kilometer per minute using the treadmill manufacturer's software (Vacu Med, TurboFit 5.05, Ventura, CA). Participants received verbal encouragement and the treadmill was stopped immediately when participants reached volitional fatigue.

Two familiarization trials were included in preliminary testing. Test meal familiarization was included at least seven days before the first trial day to introduce lentils to the diet prior to trial testing. A treadmill familiarization, completed at least

Table 3.1: Participant age, body weight, height, maximal oxygen uptake, and maximum treadmill velocity of males (n=10) and females (n=4).

Variable	Value	
	Males (SD)	Females (SD)
Age (years)	27.2 (8.0)	22.5 (4.4)
Body weight (kg)	68.3 (7.6)	63.3 (8.8)
Height (cm)	174.8 (2.0)	169.5 (5.1)
BMI (kg·m⁻²)	22.2 (1.6)	21.9 (1.8)
VO_{2max} (mL·kg⁻¹·min⁻¹)	55.8 (5.5)	54.6 (4.8)
HR_{Max} (bpm)	191 (16)	191 (13)
V_{max} (km·hr⁻¹)	17.0 (1.9)	16.3 (1.0)

SD, Standard Deviation; BMI, body mass index (kg·m⁻²); VO_{2max}, maximal oxygen uptake; HR_{max}, maximum heart rate; bpm, beats per minute; V_{max}, maximum treadmill velocity. Means for genders were not significantly different.

seven days before the first trial day, included a 90-minute treadmill run with speed variability to simulate match play. Subjects completed a detailed 48-hour activity and dietary intake record prior to the first trial day and duplicated their activity and food intake for the second day. Subjects were asked to abstain from strenuous physical activity during the 24 hours before a trial. During the trials, subjects were not allowed to consume foods other than those provided for the study. Water was provided throughout the first soccer match *ad libitum* and intake was duplicated as closely as possible for the second trial day.

3.4.2 Experimental meal conditions

In a randomized counterbalanced fashion, subjects received either a low GI, high protein meal (estimated $GI_{\text{glucose}} = 36$, determined $GR_{\text{white bread}} = 46$) or an isocaloric, high GI, low protein meal (estimated $GI_{\text{glucose}} = 76$, **Table 3.2**). The low GI, lentil-based meal was comprised of red lentils (SaskCan Pulse Trading, Regina, SK), Saskatoon berries (Moonlake Saskatoon Berry Farm, Saskatoon, SK), and liquid honey (Laprell's Beehive Products, North Battleford, SK). The LGI meal was developed to supply $1.5 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$ of CHO, as previously described (see also **Appendix 3**) [6, 8].

The HGI potato-based meal was comprised of instant mashed potatoes (Idahoan Instant Mashed Potatoes, Idahoan Foods LLC, Lewisville, ID) and white bread (Safeway White Bread Texas Toast, Canada Safeway Limited, Calgary, AB, **Table 3.2**). These meals, used previously by Little et al. [50], were chosen based on the glycemic index of these foods to maximize treatment fidelity as well as compare LGI, high protein and HGI, low protein pre-exercise meals.

A second interim meal, with the exact composition of the first meal, was consumed within an hour of completing the first match. The portions of the interim meal were provided based on recommendations of 30 g CHO to be consumed for every hour of endurance activity ($1.5 \text{ hrs} \times 30 \text{ g CHO}$) to replace any CHO losses during the first match, in addition to the CHO recommendations for upcoming exercise ($2.0 \text{ g CHO} \cdot \text{kg} \text{ bw}^{-1}$) [3].

The caloric content of the two meals was calculated and matched based on the Canadian Nutrient File [146] and the United States Department of Agriculture nutrient

Table 3.2 Test meal characteristics for a 70 kg participant.

		Low GI meal	High GI meal
Description		444 g red lentils, 24 g honey, 156 g Saskatoon berries	303 g instant mashed potatoes, 133 g white bread
Meal	Energy (kcal)	646 ± 14	646 ± 14
Content	CHO _a (g)	105	92
	Fat (g)	3	13
	Protein (g)	36	16
	Fibre (g)	24	7
	GI ₁	36	75
	GL	44	84

Macronutrient breakdowns for each meal were calculated using manufacturers' information and cross-referenced with Canadian Nutrient File data. CHO_a, available carbohydrates; GL, glycemic load. 1- Calculated according to Wolever and Jenkins [150] using GI values from Foster-Powell et al. [41].

segment was repeated three times to represent the first half of a soccer match (0 to 45 minutes) followed by a 15-minutes resting break (45 to 60 minutes). The second half of the soccer match was comprised of two more 15-minute segments (60 to 90 minutes). For the last 15-minutes of match 1 (90 to 105 minutes), subjects completed five one-minute maximal sprints separated by two and a half-minute rest periods to determine performance at the end of the match.

The treadmill speeds of exercise intensity were customized for each participant, based on the V_{\max} reached during their incremental $VO_{2\max}$ test. A primary goal of the simulated soccer tournaments was to induce high levels of fatigue and muscle glycogen depletion observed during extended intermittent exercise. Reductions to treadmill protocols were made for participants exhibiting high levels of fatigue at the end of the first match, to ensure they were able to complete both soccer matches. For six of the 14 participants, the second match was reduced in speed by $0.5 \text{ km} \cdot \text{hr}^{-1}$ for the walking and jogging speeds and by $1.0 \text{ km} \cdot \text{hr}^{-1}$ for the running and sprinting speeds. Table 3.3 shows the resultant mean speeds for each movement category.

At the end of the fifth simulation segment (90 minutes), participants then rested for 90 seconds and returned to the treadmill to walk for one minute before commencing the performance testing. Subjects completed five one-minute repeated maximal sprints separated by two and a half-minute of active recovery to determine performance at the end of the match. During each sprint, participants began at their previously identified V_{\max} and indicated with verbal commands if they wished that the speed of the treadmill be increased or decreased. Subjects were blinded to the speed and the distance of the treadmill during testing but received verbal encouragement from researchers throughout each sprint. Distance was measured by measuring number of belt rotations on the treadmill and multiplied by 3.6 metres after testing was completed. The researcher counting the distance travelled was blinded to the meal conditions.

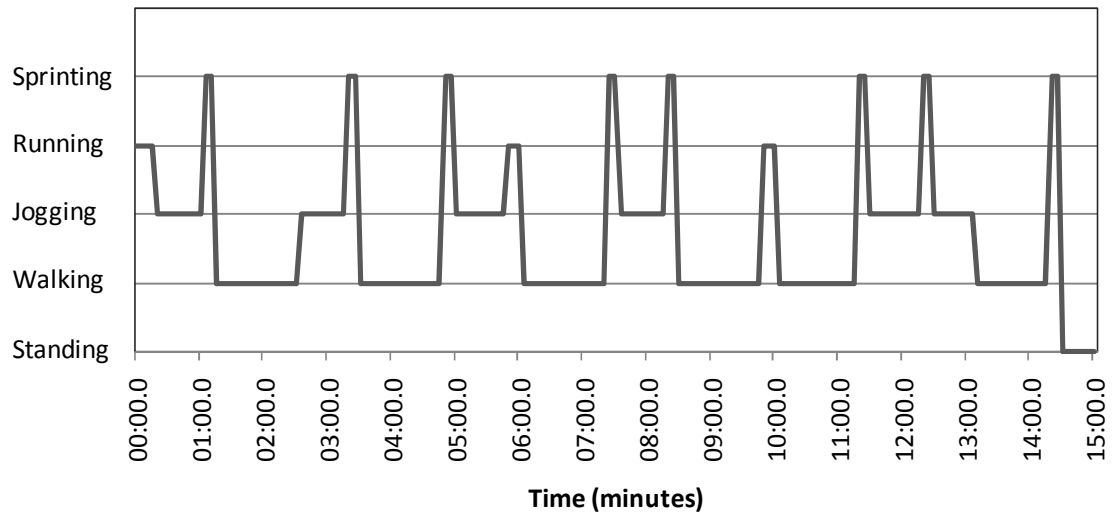


Figure 3.1: Profile of exercise intensities in a single 15-minute segment for each soccer match simulation.

Table 3.3: Intensity of walking, jogging, running, and sprinting intervals used in the treadmill simulated soccer match expressed relative to peak treadmill speed (V_{\max}). Values are mean (SD).

Match	Category	Speed ($\text{km}\cdot\text{hr}^{-1}$)	% V_{\max}
1	Walk	5.8 (0.3)	34.9 (2.5)
	Jog	9.8 (0.3)	58.9 (4.5)
	Run	15.8 (0.8)	94.5 (5.8)
	Sprint	18.9 (1.2)	112.9 (6.6)
2	Walk	5.6 (0.4)	33.8 (2.5)
	Jog	9.6 (0.4)	57.8 (4.4)
	Run	15.4 (1.0)	92.4 (6.3)
	Sprint	18.4 (1.3)	110.3 (7.5)

3.4.4 Questionnaire development and administration

An 11-page questionnaire was developed to evaluate athletes' beliefs and barriers to pulse-based meals (**Appendix 5**). Beliefs and barriers to pulse-based meals were evaluated by adapting a questionnaire previously used to determine barriers to plant-based diets [100]. Wording of questions relating to “plant-based diets” were replaced with “pulse-based meals”. The definition of pulses was provided at the beginning of the questionnaire, stating “Pulses, also referred to as legumes, are seeds of plants. These include beans (kidney beans, white beans, black beans, navy beans), soy beans, chickpeas, peas (i.e split peas), and lentils (red, yellow, and green)”. A total of 22 barriers-related questions and 17 beliefs-related questions were included in the questionnaire. Nutritional knowledge was assessed using a 76-question athlete nutritional knowledge questionnaire (NKQ) [80]. Demographics and health behaviours were also assessed. Respondents were asked to report age, gender, the number and age of members living in their household, income, employment, and education level. Health related questions included frequency of participation in healthy eating strategies, frequency and duration of exercise, current consumption of pulses and lentils, and self-rated health. Ten participants in the pilot study completed the questionnaire during the rest periods between blood samples during their first visit to the lab. During the principle investigation, fifteen participants completed the questionnaire during the three hour rest period between the two soccer matches during their first trial day. Participants were not advised on any components of the questionnaire, but were encouraged to complete it in two or three parts to reduce respondent apathy [152].

3.3 Experimental protocol

Subjects participated in two experimental trials separated by at least seven days. The meals were delivered in a single-blind, randomized counterbalanced fashion; experimenters measuring performance were unaware of the test meal consumed on that day. Each testing day required participants to attend the lab for eight hours and thirty minutes (**Table 3.4**). Subjects arrived at the exercise laboratory between 6:00 a.m. and 7:00 a.m. on the University of Saskatchewan campus after a 12-hour fast. Baseline measurements of capillary blood glucose and blood lactate were obtained immediately using commercial meters (AccuCheck Compact Plus, Roche Diagnostics, Mannheim,

Table 3.4 Timeline and measures during experimental protocol*

	Time (minutes)															
	Pre-exercise					First Half – First Match					Half-time	Second Half – First Match				
	-120	-105	-90	-60	0	3-10	15	30	33-40	45-60	63-70	75	90	90-105	105	
Measure																
Finger tip blood sample (glucose and lactate)	X	X	X	X	X		X			X			X		X	
Gastrointestinal symptoms	X	X	X	X	X		X	X		X		X	X		X	
Meal consumption	X															
Blood sample from forearm vein (fatty acids, insulin)					X					X					X	
Expired gas collection						X			X		X					
RPE							X			X			X		X	
Repeated Sprint Test								X						X		
*Protocol design for a single match was previously described by Little [50].																

Table 3.4 continued

Time (minutes)													
			Match 2										
3 Hour Rest			First Half – Second Match						Half-Time	Second Half – Second Match			
Measure	105-165	165-284	288-295	300	315	330-345	348-355	360	375	390	395	288-295	
Finger tip blood sample (glucose and lactate)			X		X		X			X		X	
Gastrointestinal symptoms			X		X		X			X		X	
Meal consumption	X												
Blood sample from forearm vein (fatty acids, insulin)			X				X					X	
Expired gas collection				X		X							
RPE					X		X			X		X	
Repeated Sprint Test													X

Germany; Accutrend GC, Roche Diagnostics, Mannheim, Germany). Gastrointestinal symptoms were determined using a 5-point scale, between 0 (no symptoms) to 4 (severe). Subjects then consumed the test meal. Similar to the pilot study (**Appendix 3**), capillary blood samples were again taken at 15, 30, 60, 90 and 120 minutes and gastrointestinal symptoms were measured at 60 and 120 minutes after meal consumption. A venous blood sample was obtained by venupuncture 120 minutes after the test meal was consumed. Subjects were then fitted with a heart rate monitor and completed a 5-minute running warm-up on the treadmill at 8 km·hr⁻¹ followed by 3 minutes of stretching. Subjects then completed the first simulated soccer match (0 to 105 minutes)

After the first match, subjects rested for three hours (105 to 285 minutes). Participants consumed a second test meal, identical in composition to the first meal, within the first hour of the rest period (105 to 165 minutes). Prior to the start of the second match, capillary blood glucose and lactate, a venous blood sample, and gastrointestinal symptoms were taken. Subjects were again fitted with a heart rate monitor and provided 5 minutes of running warm up and 3 minutes of stretching. A second match was then completed within an identical two-part time frame to the first.

For both matches, capillary blood glucose and lactate were measured at 15, 45, 90 and 105 minutes. Venous blood samples were taken at 45 and 105 minutes in addition to baseline. Breath-by-breath (BxB) analysis and heart rate (HR) were recorded at 3 to 10 minutes, 33 to 40 minutes, and 63 to 70 minutes during each soccer match. Gastrointestinal symptoms were measured at the capillary blood sample intervals. Lastly, rating of perceived exertion (RPE) was measured every 15 minutes throughout each match (15, 30, 45, 75, 90, and 105 minutes) using the Borg 15-point scale (**Appendix 4**) [139].

3.4 Respiratory and blood sample analysis

A trained phlebotomist performed all venous blood sampling using 10 mL tubes (BD Vacutainer SST). Samples were treated as per manufacturer's directions; allowed to clot for 30 minutes before centrifugation at 3000 rpm at 4°C for 10 minutes. Separated serum samples were then transferred to 3 mL microcentrifuge tubes and stored at -70°C until insulin and free fatty acid (FFA) analysis at a later date. Insulin values were

determined using an enzyme linked immunosorbent assay (ELISA; Insulin EIA, Alpco Diagnostics, Salem, USA) and were analyzed in duplicate according to the manufacturer's directions. The FFA assay was also performed in duplicate and based on the oleic acid standard solution included with the kit (NEFA-HR(2), Wako Diagnostics, Richmond, VA) using a 96-well plate protocol as per the manufacturers directions. The coefficients of variation for the insulin and FFA kits were $\leq 10\%$.

Expired gas samples were collected for seven minutes at each time point. Oxygen uptake (VO_2), Carbon dioxide output (VCO_2), and respiratory exchange ratio (RER) were measured breath-by-breath using open circuit indirect calorimetry (Sensor Medics, Vmax Series 29, Anaheim, CA). Respiratory gases were used to calculate CHO and fat oxidation. Substrate oxidation rates were based on calculations by Jeukendrup and Wallis for moderate to high intensity exercise [153] (Equation 3.1 and 3.2).

$$\text{CHO oxidation rate (g}\cdot\text{min}^{-1}\text{)} = 4.210 \times \text{VCO}_2 - 2.962 \times \text{VO}_2 \quad 3.1$$

$$\text{Fat Oxidation Rate (g}\cdot\text{min}^{-1}\text{)} = 1.695 \times \text{VO}_2 - 1.701 \times \text{VCO}_2 \quad 3.2$$

3.5 Data analyses

All statistical analyses were performed using SPSS for Windows software (v 14.0; SPSS Inc. Chicago, IL). All data are described as means and standard deviations (SD), all figures are identified as means and standard error (SE). Baseline levels for blood glucose and blood lactate between the two treatments were compared using a paired T-test. Blood glucose, blood lactate, RER, carbohydrate oxidation, fat oxidation, HR, expired gases, serum insulin, serum FFA, RPE, and sprint performance were analyzed using a repeated measures ANOVA (treatment versus time). Where significance was noted, a least significant difference post-hoc test was used to determine where significant existed. Level of significance was set at $p < 0.05$.

Nutritional knowledge questionnaire scores were condensed such that “strongly agree” and “agree” represented “agree” or “true”, “disagree” and “strongly disagree” represented “disagree” or “false”. “Unsure” was left as its own category and participants received no points for this answer. Overall and topic-specific scores were then calculated. Beliefs and barriers responses were condensed such that “strongly agree” and

“agree” represented “agree”, “disagree” and “strongly disagree” represented “disagree”, and “neither agree nor disagree” remained in a single response. Questionnaire results were analyzed using correlations to identify if any relationships existed between factors of beliefs and barriers, gender, age, pulse and lentil consumption, and NKQ scores. Correlations were considered significant if $p < 0.05$.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Blood sample analysis

Baseline blood glucose was not different at the start of the LGI and HGI trials ($p=0.67$). Blood glucose showed a treatment versus time interaction ($F=7.2$, $p<0.001$, $n=14$; **Figure 4.1**). Post hoc tests showed blood glucose was significantly higher in the HGI trial than in the LGI trial during the post-prandial period at 30 (6.86 ± 1.30 vs. 8.97 ± 2.15 mmol·L⁻¹), 60 (5.85 ± 1.13 vs. 7.60 ± 1.24 mmol·L⁻¹), and 90 minutes (5.55 ± 0.73 vs. 7.33 ± 1.90 mmol·L⁻¹). Blood glucose was significantly higher during the LGI trial, in comparison to the HGI trial, at 375 minutes after the second match and before the second set of sprints (5.42 ± 0.85 vs. 4.85 ± 0.55 mmol·L⁻¹). Blood glucose was significantly higher than baseline at time points 15, 30, and 60 minutes post-prandial and at the first half time break for both treatments (45 minutes; $F=17.2$, $p<0.001$).

Baseline blood lactate did not vary between treatments ($p=0.93$). A treatment versus time effect was noted for blood lactate levels, indicating that these levels were significantly higher in the HGI trial compared to the LGI trial ($F=8.50$, $p=0.019$, $n=12$; **Figure 4.2**). Post hoc analysis showed the LGI meal elicited a significantly higher lactate response in comparison to the HGI meal during the post-prandial period at 30 (2.3 ± 0.4 vs. 1.7 ± 0.4 mmol·L⁻¹) and 60 (2.8 ± 1.7 vs. 1.8 ± 0.4 mmol·L⁻¹) minutes. In contrast, blood lactate was higher before the second set of sprints (375 minutes; 2.6 ± 1.5 vs. 6.6 ± 5.3 mmol·L⁻¹) for the HGI meal. Lactate levels rose above baseline at 45, 90, 105, 375 and 390 minutes during exercise for both treatments ($F=81.0$, $p<0.001$).

A significant time effect was apparent for serum FFA ($F=38.3$, $p<0.001$, $n=10$) where FFA levels increased throughout both soccer matches on each day (**Figure 4.3**). No treatment effect was observed between trials ($F=2.1$, $p>0.08$, $n=10$). The mean FFA

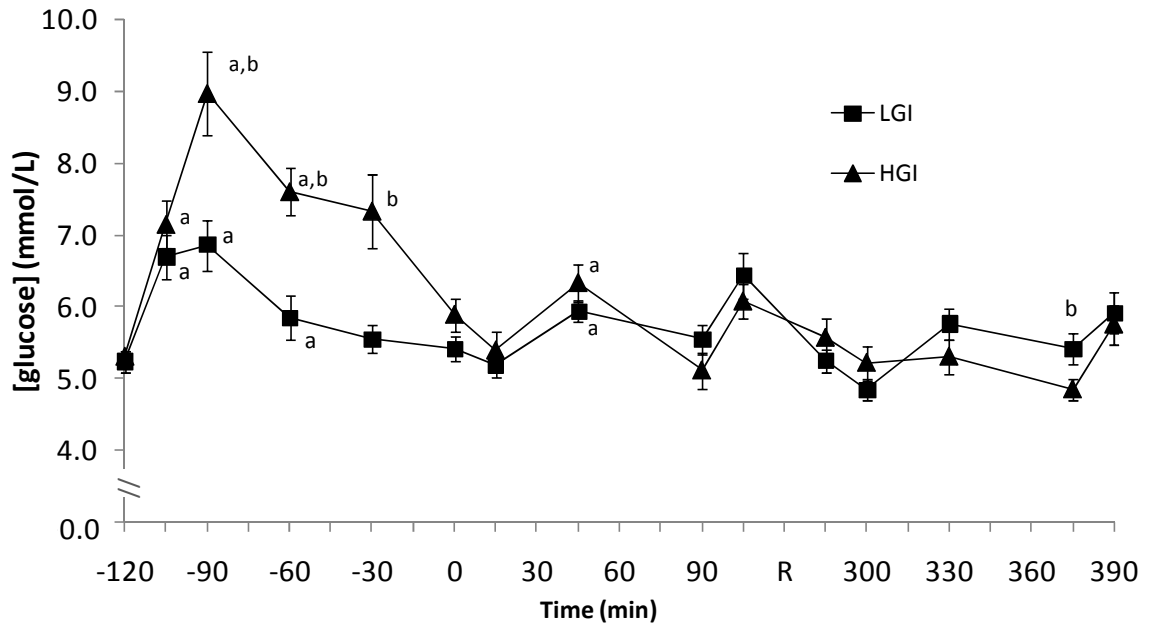


Figure 4.1: Blood glucose concentration versus time, at: baseline (-120 minutes), post-prandially (-105 to 0 minutes) and during exercise (0 to 105 minutes, and 285 to 390 minutes) with the ingestion of high glycemic index (HGI) and low glycemic index (LGI) meals (n=14). Values are mean \pm SE. Time R represents a 3 hour rest. Grey bar indicates ingestion of meal; no bar indicates rest period; solid bar indicates exercise; checker bar indicates match half-time break. Significant differences are also shown: (a) $p < 0.05$ from baseline (-120) and (b) $p < 0.05$ from HGI.

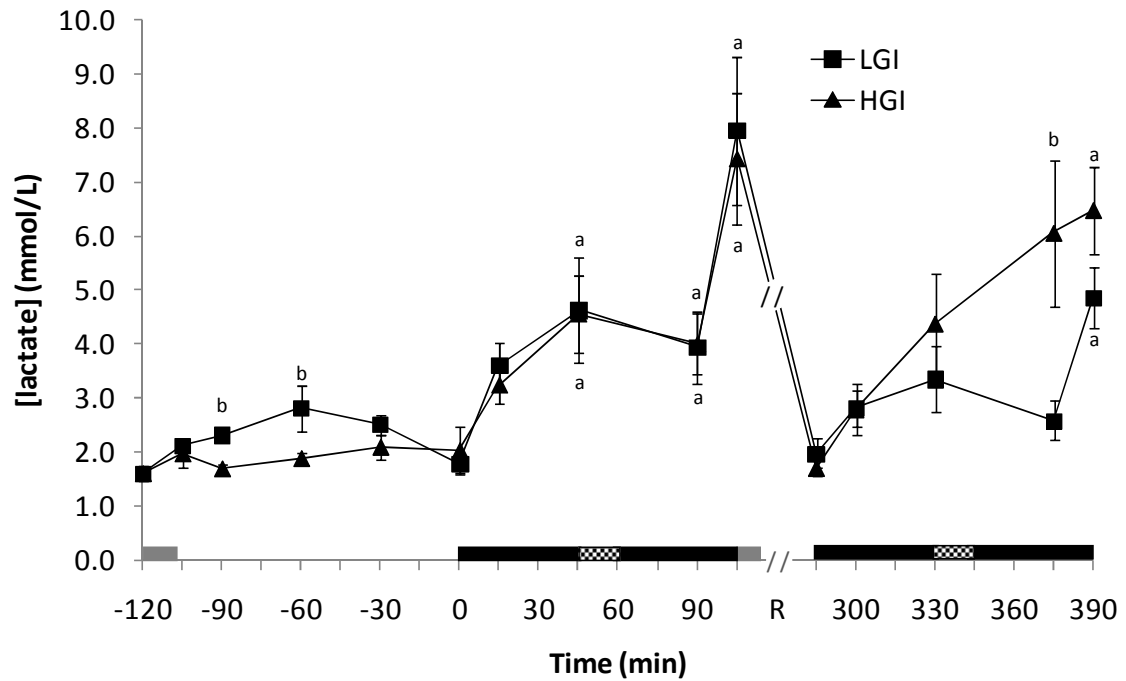


Figure 4.2: Blood lactate concentration versus time, at: baseline (120 minutes), post-prandially (30 to 120 minutes) and during exercise (0 to 105 minutes; 285 to 390 minutes) with the ingestion of HGI and LGI meals (n=12). Values are mean \pm SE. Time R represents a 3 hour rest. Grey bar indicates ingestion of meal; no bar indicates rest period; solid bar indicates exercise; checker bar indicates match half-time break. Significant differences are also shown: (a) $p < 0.05$ from baseline (-120) and (b) $p < 0.05$ from HGI.

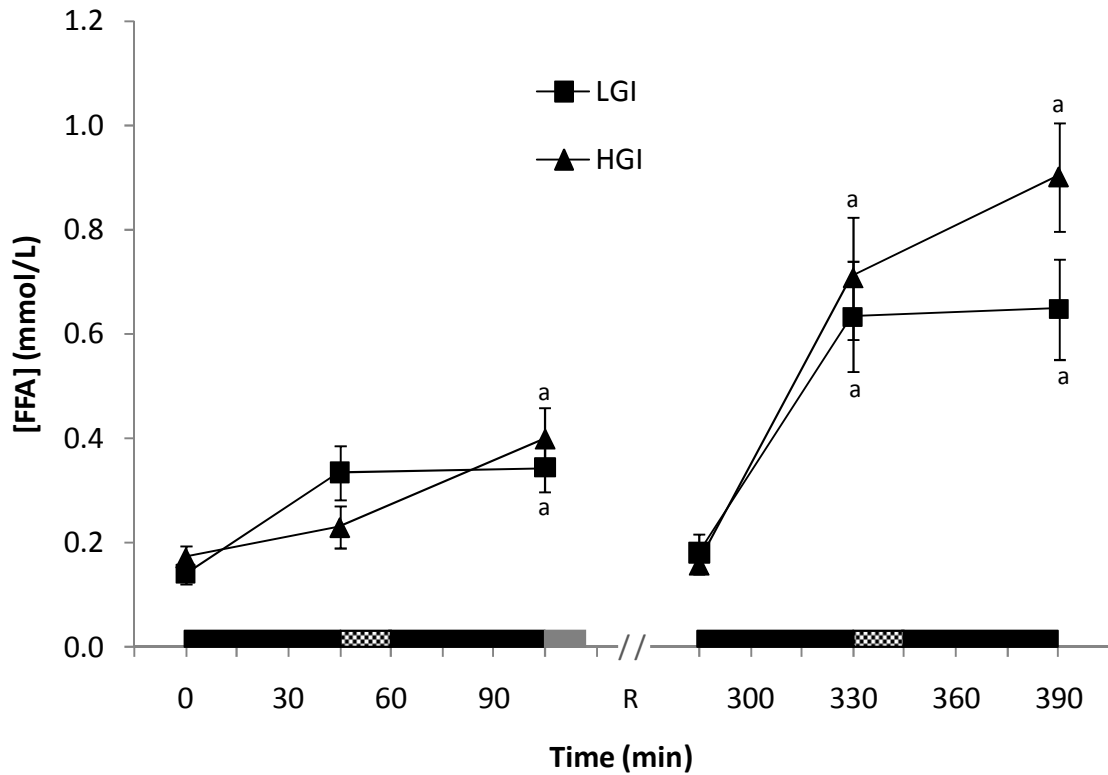


Figure 4.3: Serum free fatty acid concentrations ([FFA]) versus time, collected before (0, 285 minutes), at half-time (45, 330 minutes) and after (105, 390 minutes) each soccer match with the ingestion of HGI and LGI meals (n=10). Values are mean \pm SE. Time R represents a 3 hour rest. Grey bar indicates ingestion of meal; no bar indicates rest period; solid bar indicates exercise; checker bar indicates match half-time break. Significant differences are also shown as (a) $p < 0.05$ from time 0.

level was 0.380 ± 0.19 and 0.428 ± 0.19 mmol·L⁻¹ for the LGI and HGI trials, respectively.

A treatment versus time interaction for serum insulin was found ($F=4.37$, $p<0.003$, $n=9$; **Figure 4.4**). Values for one participant were excluded because four of six samples fell outside two SD from the group mean. Post hoc analysis demonstrated insulin levels for the HGI trial were significantly higher than the LGI trial prior to beginning the first soccer match (17.7 ± 7.6 vs. 10.9 ± 5.23 mIU·L⁻¹).

4.1.2 Substrate oxidation

Analysis of carbohydrate oxidation showed a treatment x time for carbohydrate oxidation, ($F=2.5$, $p=0.039$, $n=14$; **Figure 4.5**). Between treatments, time point 1 (3 to 10 minutes) was significantly higher in the HGI trial than the LGI trial. A significant time effect was noted for both treatments ($F=39.5$, $p<0.001$). Rates of carbohydrate oxidation was significantly higher during time point 1 (3 to 10 minutes) than time points 3 (33 to 40 minutes), 5 (303 to 310 minutes), and 6 (348 to 355 minutes).

Fat oxidation rates increased over time during both trial days ($F=35.7$, $p<0.001$, $n=12$; **Figure 4.6**). The mean fat oxidation rate for the HGI and LGI trials was 0.184 ± 0.02 g·min⁻¹ and 0.186 ± 0.02 g·min⁻¹, respectively, but this trend did not correspond to a treatment effect ($F=2.1$, $p=0.08$).

No treatment by time interaction was evident for the RER from the trials (HGI= 0.96 ± 0.02 , LGI= 0.95 ± 0.03 ; $F=0.2$, $p=0.28$, $n=14$). RER decreased over time in both trials ($F=34.7$, $p<0.001$; **Figure 4.7**).

4.1.3 Heart rate and volume of oxygen consumed

Heart rate was not affected over time ($F=1.40$, $p=0.19$) or treatment ($F=1.5$, $p=0.29$, **Table 4.1**). The mean HR response, averaged for each of the same time points with the breath-by-breath analysis, was 150 ± 4.2 and 145 ± 4.1 bpm for the HGI and LGI meals, respectively.

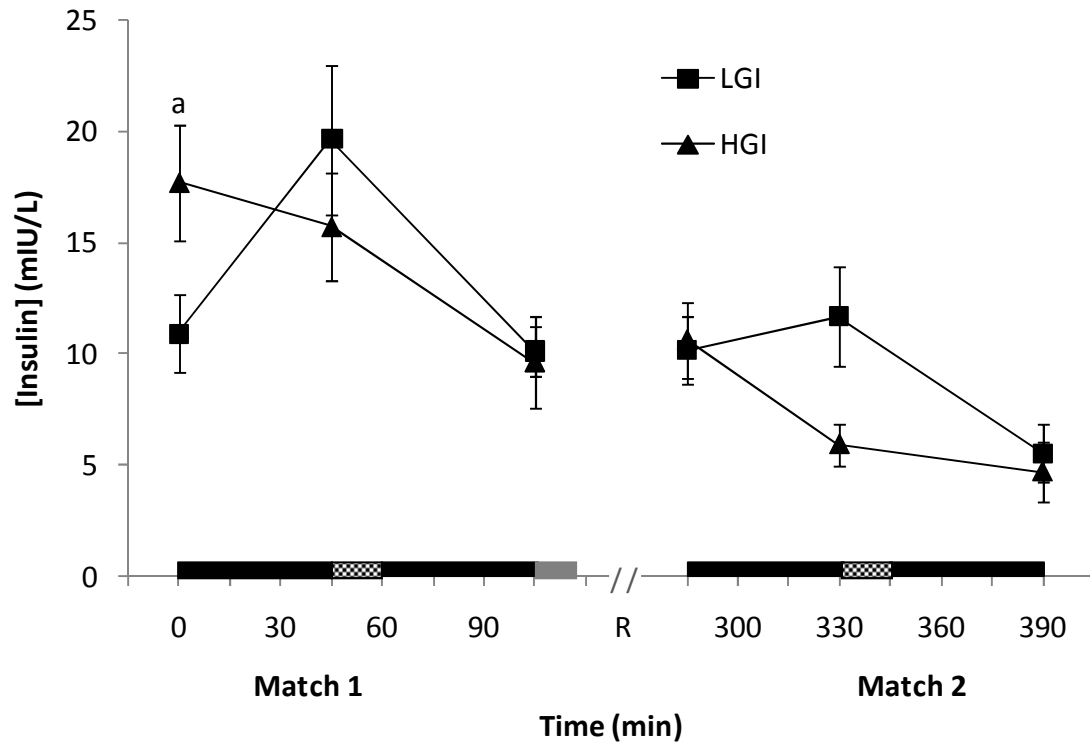


Figure 4.4: Serum insulin concentrations throughout each simulated soccer match. Samples were collected before (0, 285 minutes), at half-time (45, 330 minutes) and after (105, 390 minutes) each soccer match with the ingestion of HGI or LGI meals (n=9). Values are mean \pm SE. Time R represents a 3 hour rest. Grey bar indicates ingestion of meal; no bar indicates rest period; solid bar indicates exercise; checker bar indicates match half-time break. Significant differences are also shown as (a) HGI compared with LGI, $p < 0.05$.

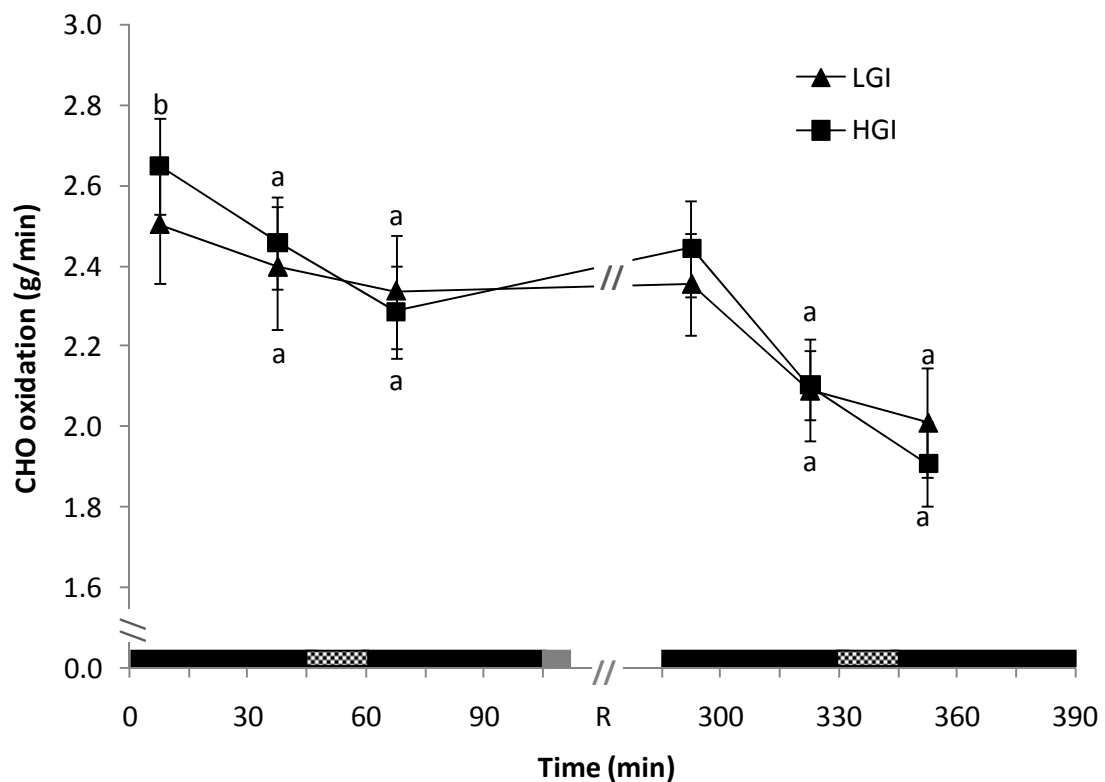


Figure 4.5: Average rate of carbohydrate (CHO) oxidation versus time, from gas collected for 7-minute periods at the beginning (3 to 10 minutes) ingestion before half time (33 to 40 minutes) and after half time (63 to 70 minutes) for each match after of HGI or LGI meals (n=14). Values are mean \pm SE. Time R represents a 3 hour rest. Grey bar indicates ingestion of meal; no bar indicates rest period; solid bar indicates exercise; checker bar indicates match half-time break. Significant differences are also shown as (a) $p < 0.05$ from time zero and (b) $p < 0.05$ from HGI.

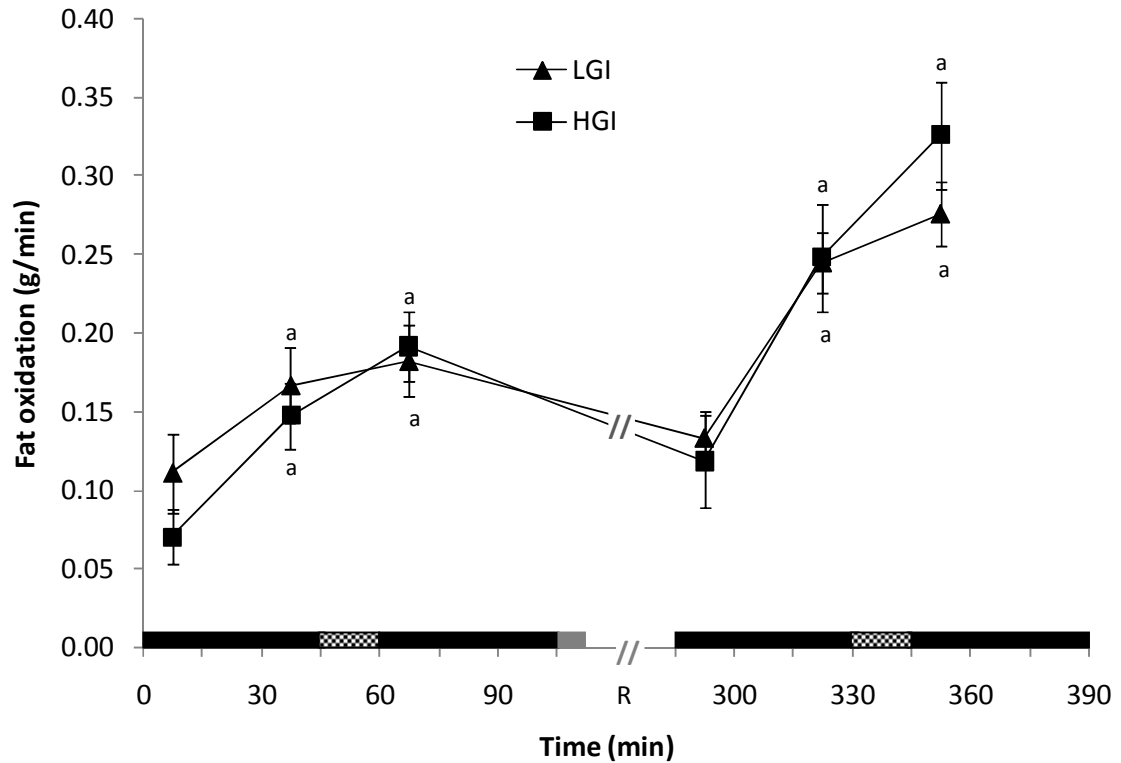


Figure 4.6: Average rate of fat oxidation collected during each soccer match. Measured from respiratory gases collected for 7-minute periods at the beginning (3 to 10 minutes) before half time (33 to 40 minutes) and after half time (63 to 70 minutes) for each match after ingestion of HGI or LGI meals. Values are mean \pm SE. Time R represents a 3 hour rest. Grey bar indicates ingestion of meal; no bar indicates rest period; solid bar indicates exercise; checker bar indicates match half-time break. Significant differences are also shown as (a) $p < 0.05$ from time point 1 (3 to 10 minutes).

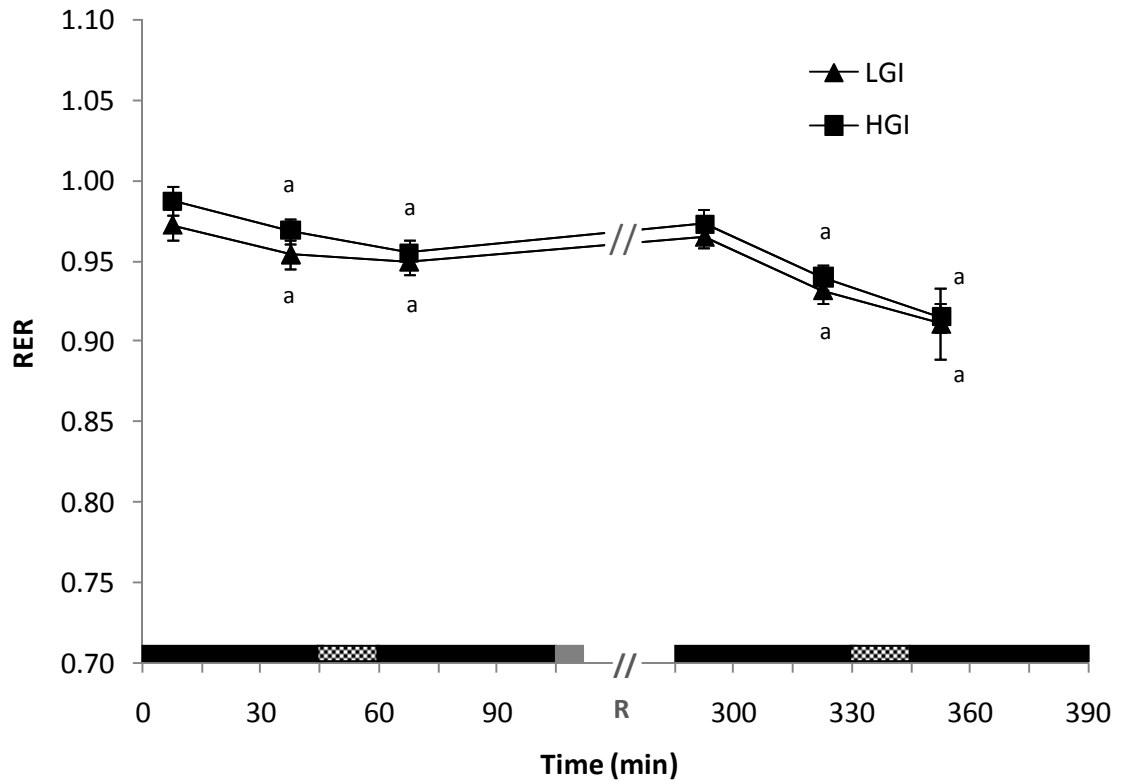


Figure 4.7: Respiratory exchange ratio (RER) throughout each simulated soccer match. Values were analyzed from gas collected for 7-minute periods at the beginning (3 to 10 minutes) before half time (33 to 40 minutes) and after half time (63 to 70 minutes) for each match after ingestion of HGI or LGI meals (n=14). Values are mean \pm SE. Time R represents a 3 hour rest. Grey bar indicates ingestion of meal; no bar indicates rest period; solid bar indicates exercise; checker bar indicates match half-time break. Significant differences are also shown as (a) $p < 0.05$ from time point 1 (3 to 10 minutes).

Table 4.1 Rate of perceived exertion, heart rate, and VO₂ during each simulated match

	min	15	30	45	75	90	105		285	300	315	360	375	390
RPE	HGI	11.6 ± 1.4	12.3 ± 1.1	12.9 ± 1.4	13.4 ± 1.6	14.1 ± 1.7 ^a	16.6 ± 1.5 ^a		13.1 ± 1.5	13.7 ± 1.7	14.4 ± 1.8 ^a	15.2 ± 1.7 ^a	15.5 ± 1.7 ^a	17.7 ± 1.8 ^a
	LGI	11.6 ± 2.0	12.5 ± 1.4	13.0 ± 1.2	13.4 ± 1.4	13.9 ± 1.7 ^a	16.2 ± 2.0 ^a		13.1 ± 1.4	13.8 ± 1.7	14.6 ± 1.3 ^a	14.8 ± 1.6 ^a	15.2 ± 1.6 ^a	17.4 ± 2.1 ^a
HR	HGI	143 ± 14		150 ± 16 ^a	146 ± 13 ^a				150 ± 15 ^a		148 ± 12	145 ± 17		
	LGI	140 ± 14		146 ± 14 ^a	145 ± 14 ^a				141 ± 14 ^a		143 ± 20	146 ± 19		
VO ₂	HGI	33.7 ± 2.3		33.7 ± 2.5	32.9 ± 3.8				32.4 ± 2.8 ^a		32.3 ± 2.4 ^a	32.1 ± 2.5 ^a		
	LGI	33.1 ± 2.2		33.5 ± 2.3	33.5 ± 2.3				32.0 ± 2.5 ^a		31.9 ± 2.2 ^a	31.6 ± 2.7 ^a		

RPE, rate of perceived exertion rated on a 15-point scale from 6 to 20 (**Appendix 4**) [14]; HR, heart rate; bpm, beats per minute; VO₂, volume of oxygen consumed per minute relative to body mass. a, value significantly different than time point 1 (15 minutes)

When expressed as a percentage of relative VO_2max , analysis showed decrease in VO_2 collected over time ($F=8.26$, $p<0.001$), but VO_2 was not effected by treatment (60.2 ± 5.3 vs. $59.9 \pm 4.7 \text{ L} \cdot \text{min}^{-1}$, $p=0.42$; **Table 4.1**).

4.1.4 Rating of perceived exertion and sprint performance

RPE data collected throughout both matches showed a significant time effect ($F=49.8$, $p<0.001$; **Table 4.1**). As expected, RPE increased over time during both matches. The peak response for RPE, recorded at the end of the second match sprints, was 17.4 ± 0.6 and 17.7 ± 0.5 for the HGI and LGI trials, respectively. RPE was not influenced by meal GI, with a mean response of 14.1 ± 0.3 and 14.2 ± 0.3 for the HGI and LGI trials, respectively ($F=0.54$, $p=0.867$).

Thirteen participants were able to complete all five sprints at the end of each match, and one subject could only complete the first two sprints at the end of the second match due to knee pain on the last day of testing. Sprint performance at the end of each soccer match was not significantly affected by the glycemic index of the pre-exercise test meal ($F=1.31$, $p=0.27$). A main effect for time ($F=5.37$, $p<0.001$) was observed (**Figure 4.8**).

4.1.5 Gender differences

The third objective of the study was to determine the differences between male and female participants, if any existed. Due to the number of female participants who were unable to complete the testing protocol, this objective could not be evaluated. Though nine females were recruited, five failed to complete testing. Of those five, four dropped out due to injury procured, or exacerbated, by the treadmill running in the study protocol. Due to the drop out rate from injury, no efforts were made to recruit more female participants to the study.

4.1.6 Gastrointestinal symptoms rating scale

Baseline ratings of fullness, hunger, bloating, nausea and abdominal cramps were similar between all trials ($p>0.05$). After meal consumption, there was a significant different in ratings of perceived hunger following the HGI meal (1.6 ± 0.2) in comparison to the LGI meal (0.9 ± 0.2 ; $F=6.37$, $p<0.001$, $n=14$, **Figure 4.9**). During the LGI trial,

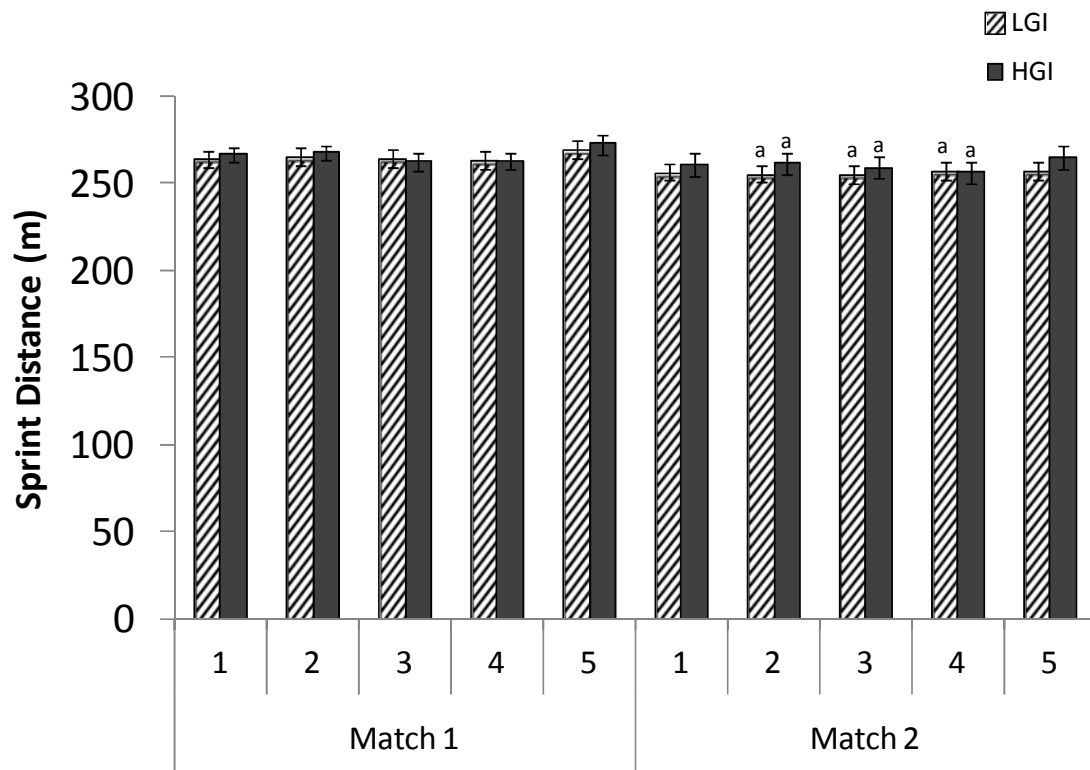


Figure 4.8: Distance travelled in meters in each one-minute sprint at the end of each soccer match after ingestion of a LGI or HGI meal. Sprints separated by 2.5-minute active recovery (n=13). Values are mean \pm SEM. Significant differences are also shown as (a) from fastest sprint of the day (Match 1, sprint 5), $p < 0.001$.

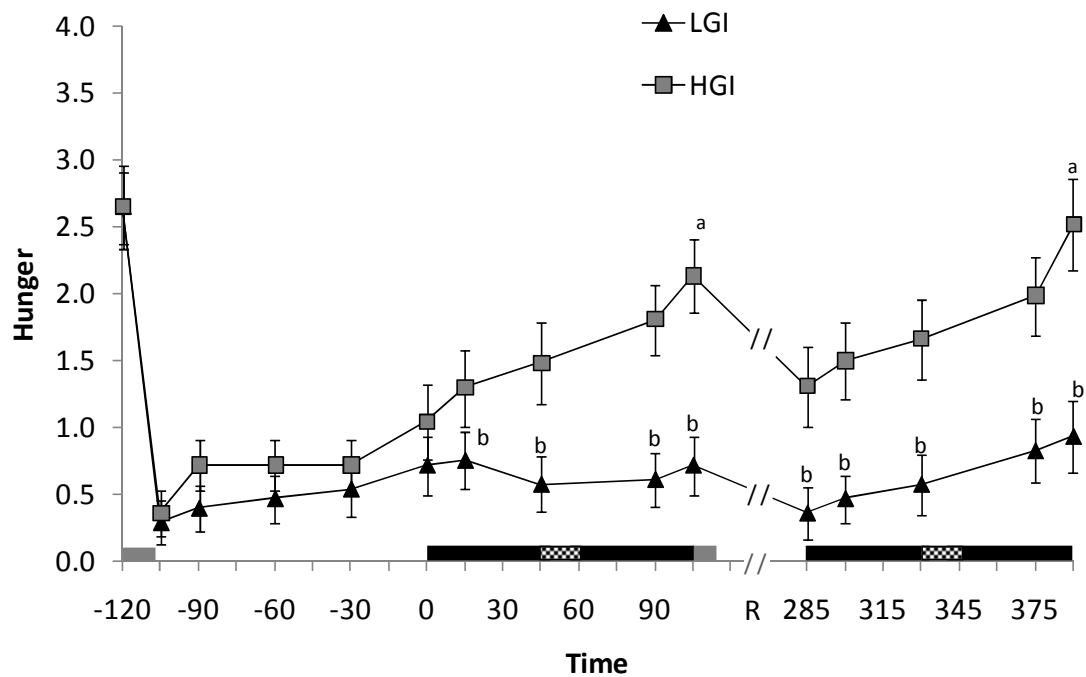


Figure 4.9: Rating of hunger versus time over both simulated matches.

Symptoms were rated on a five point scale from 0 (no symptoms) to 4 (severe symptoms) at baseline (-120 minutes) post-prandially, and during exercise (0 to 105 minutes; 285 to 390 minutes) with the ingestion of HGI and LGI meals (n=14). Values are mean \pm SE. Time R represents a 3 hour rest. Grey bar indicates ingestion of meal; no bar indicates rest period; solid bar indicates exercise; checker bar indicates match half-time break. Significance is also shown as (a) $p > 0.05$ similar to baseline, (b) $p < 0.001$ different from HGI.

ratings of hunger never returned to baseline after consumption of the first test meal. Ratings of hunger during the HGI trial returned to baseline after the performance sprints (105 and 390 minutes).

A concomitant difference between LGI and HGI reported hunger and fullness was observed, as may be expected. Ratings of fullness were significantly higher during the LGI trial than the HGI trial ($F=3.92$, $p<0.001$, $n=14$, **Figure 4.10**). While fullness never returned to baseline during the LGI trial after consumption of the first meal, during the HGI trial fullness ratings returned to baseline prior to and following the performance sprints (90, 105, 375 and 390 minutes).

Adverse symptoms of bloating, nausea and abdominal cramps were not significantly different between the treatments ($F=1.486$, $p=0.182$; $F=0.936$, $p=0.483$; $F=0.525$, $p=0.813$, respectively).

4.1.7 Questionnaire responses

4.1.7.1 Demographic information

Respondents to the questionnaire were 26 males and 11 females with a mean age of 25 ± 5 years. No significant relationship for age and gender were noted when correlations were performed for NKQ score, pulse consumption, or beliefs and barriers. In total, 64% of respondents were students with some part-time or full-time employment and an additional 14% were students with no employment. Almost all (95%) respondents had some university, completed university, or some graduate education. When asked to report their specific nutrition education, 32% reported some university-level nutrition education while 25% reported having no nutrition training. Nine respondents identified “other” nutrition training and described some form of team or personalized sports nutrition instruction. The majority of respondents (54%) reported a household income of less than \$40,000 a year. When asked to describe their dietary patterns, no respondents reported practicing any form of vegetarianism. Nineteen percent of respondents said their dietary habits were influenced by their cultural or ethnic background. Thirty-two per cent of respondents reported consuming one serving of pulses each week, while 25% said they did not consume pulses once a week. The majority of respondents also reported that they

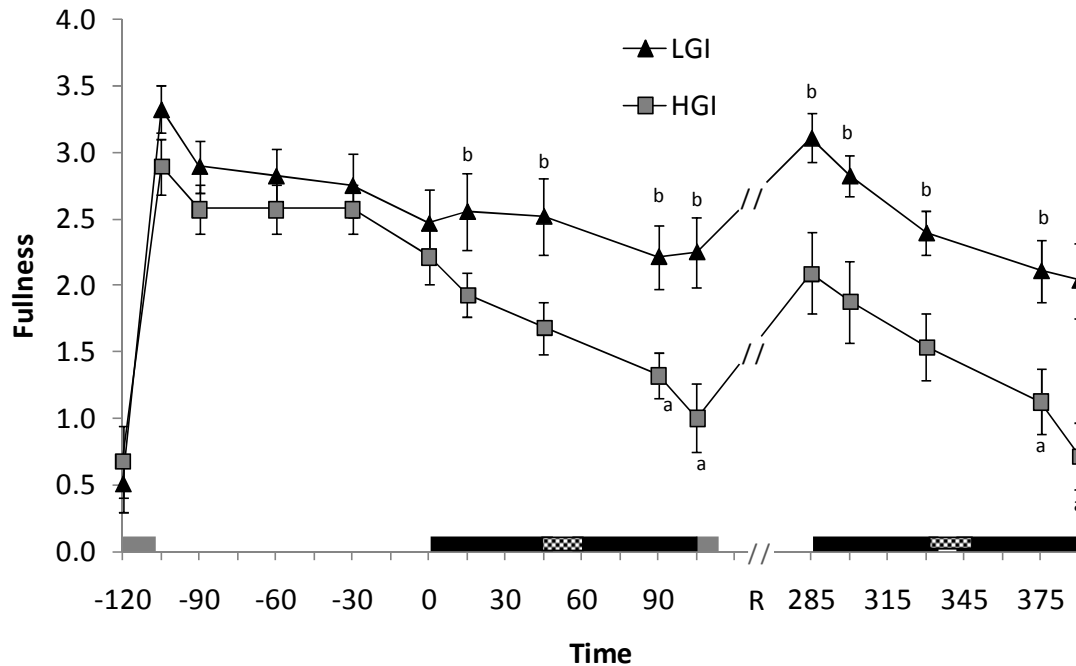


Figure 4.10: Rating of fullness versus time over both simulated matches.

Symptoms were rated on a five point scale from 0 (no symptoms) to 4 (severe symptoms) at baseline (-120 minutes) post-prandially, and during exercise (0 to 105 minutes; 285 to 390 minutes) with the ingestion of HGI and LGI meals (n=14). Values are mean \pm SE. Time R represents a 3 hour rest. Grey bar indicates ingestion of meal; no bar indicates rest period; solid bar indicates exercise; checker bar indicates match half-time break. Significance is also shown as (a) $p > 0.05$ similar to baseline and (b) $p < 0.001$ different from HGI.

consumed no lentils in their weekly diets. Detailed distributions of responses are reported in **Figure 4.11** and **4.12**. Finally, the most frequent response for self-rated health was “very good” (57%), while an additional 24% rated their health as “excellent”.

4.1.7.2 Nutritional knowledge questionnaire scores

The mean score for the NKQ was 61.5% with a range between 22.0 and 86.0% (**Table 4.2**). The test also showed a skewed negative distribution, as identified through a negative z-score for skewness of -2.43. The mean score for the athlete nutrition subsection was $49 \pm 15\%$. Bivariate analysis showed formal nutrition training and education level positively correlated to overall ($p < 0.05$, $n = 37$, $r = 0.43$, and $r = 0.35$, respectively) and athlete specific NKQ score ($p < 0.05$, $n = 37$, $r = 0.37$ and $r = 0.41$, respectively). There was no correlation between overall or athlete specific NKQ scores and gender ($p > 0.05$, $n = 37$, $r = 0.131$ and $r = 0.09$). Finally, the number of reported exercise sessions per week correlated to NKQ score ($r = 0.34$, $p < 0.05$) and athlete specific NKQ score ($r = 0.39$, $p < 0.05$).

Most respondents had high scores for the attitudinal question subsection. Thirty-seven per cent of respondents had appropriate responses to eleven statements and 40% agreed with ten of the eleven statements. All 37 respondents agreed with statements regarding nutrition and performance including “The relationship of good eating habits to good health should be stressed to the athlete” and “The type of food an athlete eats affects their physical performance”. Only 24 respondents agreed with the statement “It is the coaches’ responsibility to stress good nutrition practices” whilst 26 respondents agreed with the statement “Nutrition is more important during the competitive season than during the off-season for the athlete”.

4.1.7.3 Beliefs and barriers

Correlation analysis showed no relationship between agreement with barriers or beliefs about pulse-based meal consumption and pulse or lentil consumption. Respondents tended to disagree with barriers associated with pulse-based meal consumption. Percentages of responses are listed in **Table 4.3**. By rank, the most prevalent barriers corresponded to practical barriers. Forty-eight per cent of respondents agreed with the statement “I do not know how to prepare a pulse-based meal”. Statements

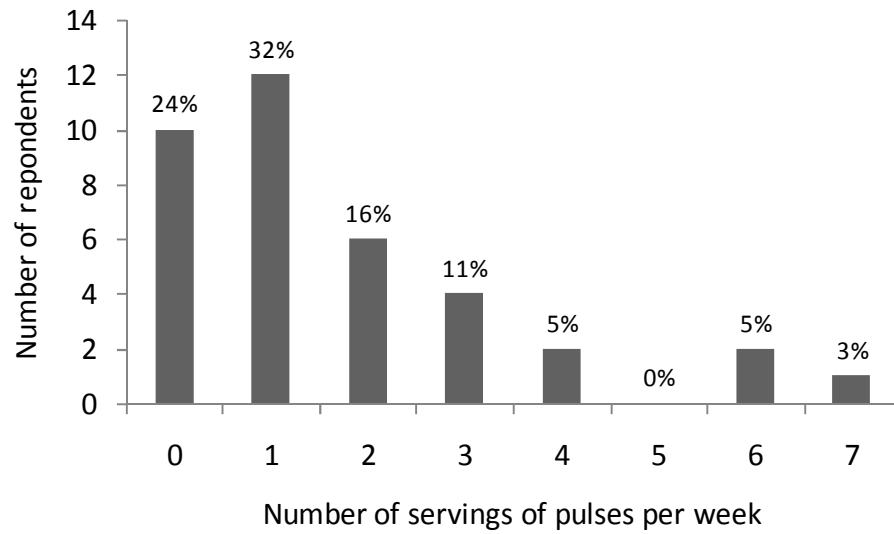


Figure 4.11 Number of servings of pulses reported by participants (n= 37). Corresponding percentage of respondents provided above each bar.

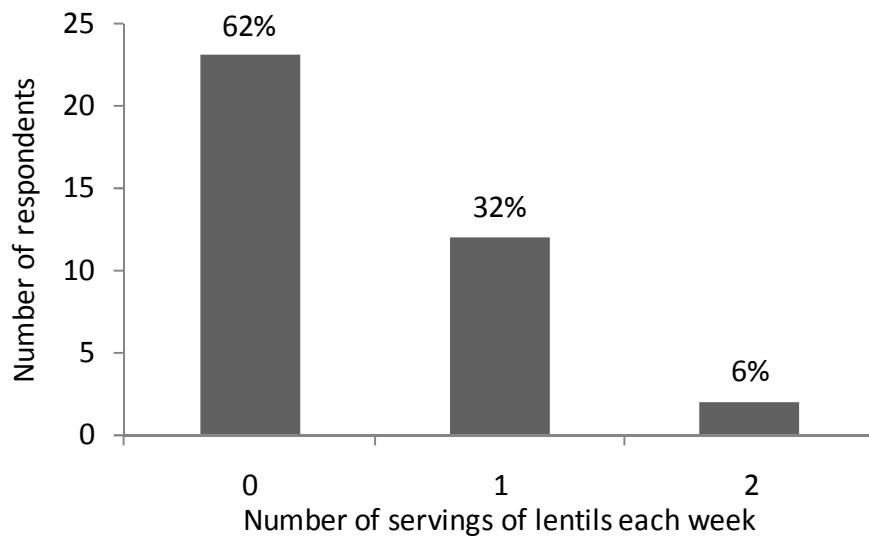


Figure 4.12: Reported number of servings of lentils consumed each week (n=37). Corresponding percentage of respondents provided above each bar.

Table 4.2 Subgroup and total scores for nutritional knowledge questionnaire (n=37)

	Mean percentage score	Number of questions in category
1 Carbohydrates	50	5
2 Protein	69	3
3 Fats	52	4
4 Calcium	66	6
5 Iron	65	6
6 Vitamins	52	13
7 Functional foods	86	3
8 Vegetables	68	4
9 Health benefits of foods	48	3
10 Hydration	80	9
11 Nutrition for the athlete	50	6
12 Weight loss	61	3
Total	61	65
Results are described as categories defined previously [80].		

corresponding to limited social support were also frequently identified, such as “my family/partner won’t eat a meal containing pulses” or “someone else decides most of the foods that I eat”. Also, 33% of respondents agreed that pulse-based meals “would not be tasty enough”. Issues related to gastrointestinal discomfort (i.e. “I would get indigestion, bloating, gas or flatulence”) was usually answered as “unsure”. The only question related to self-efficacy “I do not have enough will power” was most often disagreed with.

A Pearson correlation identified the relationship between specific barriers. Issues related to routine and time allowances were significantly correlated ($p < 0.05$). These barriers included “I don’t want to change my eating habits or routine”, “I’m too busy to prepare a pulse-based meal”, “I need something that’s easier to consume on the run” and “it is inconvenient”. Results from the beliefs about the benefits of pulse-based meal consumption are listed in **Table 4.4**. Respondents agreed most often with the overall health and nutrition benefits of consuming pulse-based meals. Significant correlations were noted between belief factors. Respondents agreed with the statement “consuming pulse-based meals can help me to stay healthy”, but did not agree with the statement “consuming pulse-based meals will help me prevent disease (heart disease, diabetes) in general”. Secondly, negative correlations were noted between beliefs of the health benefits of pulse-based diets (i.e. “I believe pulse-based meals have lots of fibre”, “I believe pulse-based meals have lots of vitamins and minerals”) and social appearance question “I believe consuming pulse-based meals will make me appear more ‘trendy’ to my friends”. Moreover, “consuming pulse-based meals will make me feel more content with myself” was positively correlated to the social appearance belief ($r = 0.50$, $p < 0.05$).

Table 4.3 Percentage of total respondents (n=37) in agreement with barriers to eating pulse-based meals.

Statement	% of Respondents		
	Agree ¹	Unsure	Disagree ¹
I don't know how to prepare pulse-based meals	48	11	41
Pulse-based meals or snacks are not available when I eat out	41	7	52
I'm too busy to prepare a pulse-based meal, I need something that's easier to consume on the run	37	15	48
My family/partner won't eat a meal containing pulses	35	15	50
It would not be tasty enough	33	22	45
Someone else decides most of the foods that I eat	33	4	63
Someone else prepares my meals	33	4	63
I would have to go shopping too often	33	30	37
It would not be filling enough	30	7	63
I need more information about pulses	30	19	51
There's not enough protein in them	26	33	41
I would get indigestion, bloating, gas or flatulence	26	48	26
It would be too expensive	26	33	41
I don't want to change my eating habits or routine	22	19	59
I don't want people to think I'm strange or a hippy	22	30	48
I wouldn't get enough energy or strength	22	19	59
I don't want to eat strange or unusual foods	19	4	77
There is not enough iron in them	19	56	25
I would need to eat such a large quantity of food	19	30	51
It takes too long to prepare a pulse-based meal	19	48	33
It is inconvenient	18	37	45
I don't have enough willpower	15	26	59

(1) Agreement responses ("Strongly agree" and "agree") and disagreement responses ("Strongly disagree" and "disagree") were grouped respectively.

Table 4.4 Percentage of respondents (n=37) in agreement with statements of the benefits of eating pulse-based meals

Statement ¹	% of Respondents		
	Agree ²	Unsure	Disagree ²
Stay healthy	76	5	19
Have lots of fibre	68	19	13
Help me to eat a greater variety of foods	62	19	19
A good source of protein	60	24	16
Have lots of vitamins and minerals	57	27	16
Have a better quality of life	49	32	19
Control my weight	49	30	21
Help decrease my saturated fat intake	48	48	4
Help the environment	43	41	16
Improve my digestion	41	40	19
Be fit	30	35	35
Be a part of a tasty diet	30	35	35
Improve my energy levels throughout the day	27	57	16
Help prevent disease in general (e.g. heart disease, diabetes)	27	57	16
Save money	24	54	22
Be more content with myself	14	62	24
Look more 'trendy' to my friends	11	43	46

(1) Questions were lead with “I believe that pulse-based meals can help me to” or “I believe that pulse-based meals can” or “I believe pulse-based meals are”

(2) Agreement responses (“strongly agree” and “agree”) and disagreement responses (“strongly disagree” and “disagree”) were grouped respectively.

4.2 Discussion

The primary objective of this research project was to determine the metabolic and physiological effects of pre-exercise meal GI during a simulated soccer tournament (two consecutive simulated soccer matches separated by a three hour break). The data demonstrate significant changes in metabolic parameters of exercise wherein LGI pre-exercise meals conveyed improved glycemic control, lower blood lactate at the end of exercise, lower pre-exercise blood insulin and lower carbohydrate oxidation early in exercise (**Figures 4.1, 4.2, 4.5 and 4.7**). Performance outcomes, measured by distance travelled in five one-minute repeated sprints at the end of each match, were not different between treatments (**Figure 4.10**). Six hypotheses were initially formulated to investigate this objective: LGI pre-exercise meals were expected to: (i) decrease RER, (ii) decrease rate of carbohydrate oxidation, (iii) increase rate of fat oxidation, (iv) maintain higher blood glucose levels later in the tournament, (v) maintain higher of blood FFA levels during exercise, and (vi) improve performance at the end of each soccer match, in comparison to a HGI pre-exercise meal. Two of these hypotheses: a decreased rate of carbohydrate oxidation and improved maintenance of blood glucose levels during the LGI trial, were supported by the data. Low GI pre-exercise meals may present improved metabolic profiles in comparison to high GI pre-exercise meals.

A second objective of this project was to report any gastrointestinal symptoms of hunger, fullness, abdominal cramps, bloating or nausea. We expected to find no difference in adverse symptoms between the LGI and HGI treatments. Increased feelings of hunger and decreased feelings of fullness were reported during the HGI trial in comparison to the LGI trial but reports adverse symptoms were not different between trials. Therefore, the hypothesis was supported by the data.

4.2.1 Blood glucose response

The LGI meal resulted in decreased blood glucose response during the post-prandial period in comparison to the HGI meal. Based on previous investigations of the role of pre-exercise meal GI, a smaller increase in blood glucose post-prandially with the LGI treatment, in comparison to the HGI treatment would be expected [4]. Commonly, blood glucose during exercise is maintained and is not affected by varying treatments,

although higher blood glucose levels at the end of exercise have been observed in one case [8]. The digestion rate of lentils contributes to sustained blood glucose levels throughout exercise [154]. Though factors such as protein-starch interactions and antinutrient content contribute to the digestion rate of carbohydrates, the amylose and amylopectin fractions also influence their digestion and absorption [154]. Amylopectin, a larger starch molecule, is broken down slowly in the gastrointestinal tract compared to amylose. Since the starch fraction of lentils is 70% amylopectin and 30% amylose, the sustained blood glucose supply is likely due to this intrinsic characteristic [155]. Such results may be beneficial to offset the effects of reduced muscle glycogen at the end of exercise [156]. Secondly, the reduction in blood glucose at the end of exercise during the HGI trial may be due to reductions in muscle glycogen, as exercising muscles enhance uptake of blood glucose when endogenous stores are low [8, 157].

No cases of rebound hypoglycemia, a blood glucose concentration of less than 3.5 mmol·L⁻¹ at the beginning of exercise were present during either trial. Rebound hypoglycemia has been regarded as a possible mechanism for decreased athletic performance after HGI pre-exercise meal consumption but evidence supporting this theory has been inconsistent [158]. While rebound hypoglycemia is more prevalent after HGI than LGI pre-exercise meals, the majority of athletes do not experience it [159]. In those studies observing rebound hypoglycemia, protocols have included meal consumption within 45 minutes of commencing exercise, and lead to increased muscle glycogen breakdown during exercise [157-159]. In the present investigation, meals were delivered two hours prior to the start of exercise, beyond the 45-minute window in which rebound hypoglycemia commonly occurs.

Serum insulin response at the start of exercise offers further insight into the implications of metabolism during exercise. Serum insulin showed divergent profiles during each exercise trial. While insulin at the beginning of the HGI trial was significantly higher than LGI at the start of exercise, the LGI meal elicited a delayed (non-significant) spike to a similar level at the first half-time break. This result may be expected due to continual absorption of blood glucose during the LGI meals; resulting in slower increases in blood glucose to trigger insulin release [14]. After the start of

exercise, differences in serum insulin were not present. The implications of this are difficult to elucidate, as increases in insulin can have long-lasting effects to decrease lipolysis after insulin levels have returned to baseline levels [51, 52].

4.2.2 Substrate utilization

Substrate utilization changes were observed at the beginning of exercise. The carbohydrate oxidation rate was significantly higher at the beginning of the HGI trial in comparison to the LGI trial in the first match. Higher CHO oxidation in the first match may have lead to lower glucose observed in the second match [157]. Previously, HGI, high CHO diets have been reported to increase carbohydrate oxidation [5, 6, 13-15, 126], and increase glycogen depletion throughout exercise in most cases [49, 126]. Although muscle glycogen was not measured in this study, comparable reductions in blood glucose and carbohydrate oxidation correspond to depletions of muscle glycogen observed in previous studies [14]. Eighty percent of carbohydrate oxidized is provided from muscle glycogen and the remaining 20% is provided from blood glucose and liver glycogen during exercise [32]. Thus, the higher levels of blood glucose at the end of the second match during the LGI trial can be explained as a byproduct of higher muscle glycogen available during the same time point in comparison to the HGI trial.

Meanwhile, fat oxidation rates and serum FFA showed trends to greater fat oxidation and availability during the first match in the LGI trial compared to the HGI trial, but these trends were switched during the second match, where fat oxidation and serum FFA tended to be higher during the HGI trial (both $p=0.08$). In principle, increased mobilization of FFA during exercise will lead to an increased rate of fat oxidation during exercise [162]. Previous investigations have found either higher serum FFA during LGI trials [5, 9-11, 15, 126], no difference [6, 8, 12-14, 49], or in one case, lower serum FFA [49]. Similarly, fat oxidation rates have not varied between HGI and LGI in five studies [5, 6, 8, 10, 11]. In this instance, the significant increase in carbohydrate oxidation at the beginning of exercise during the HGI trial may have resulted in decreased glycogen at the end of exercise, resulting in a higher dependence on fat during the second match. Comparable RER data also demonstrate no greater reliance on fat oxidation during the

LGI trials. Similar RER between LGI and HGI trials have also been observed previously [12, 15, 49].

The observed similarity in fat oxidation during exercise can be explained by three potential mechanisms; the intensity and duration of the intermittent exercise, depletions in muscle glycogen, and the hormonal response to exercise after meal consumption. The intensity and duration of the intermittent exercise in soccer performance influences fat metabolism. Mobilization of FFAs is suppressed during high intensity exercise above 70-80 % of $\text{VO}_{2\text{max}}$ [163]. Similarly, sustained intermittent exercise results in a three-fold reduction in fat oxidation rates and elevations in CHO oxidation when compared to continuous sub-maximal exercise of the same workload [164].

Fat metabolism is further limited by hormonal regulation by insulin and catecholamines [26, 165]. Insulin response during the soccer trials was delayed during the LGI trial, but resulted in a similar insulin peak within the first hour of exercise. Insulin-induced changes in lipolysis can continue for extended periods after insulin has returned to post-absorptive levels [8, 166]. High post-prandial insulinemic response may suppress fat oxidation directly after a meal and after insulin has returned to baseline levels [46]. Decreased muscle glycogen late in endurance exercise also initiates compensatory hormonal mechanisms to increase fat oxidation [167]. Increased carbohydrate oxidation early in exercise, low blood glucose levels (possibly indicating depleted muscle glycogen) and a trend towards greater fat oxidation later in exercise, implicate such hormonal responses near the end of exercise during the HGI trial. Thus, within the available data for this study, a combination of intermittent exercise to suppress fat oxidation, and a continual absorption of glucose from the gastrointestinal tract likely altered insulin and thus lipolysis during the LGI meal yielding similar profiles to the HGI trial.

4.2.3 Lactate production

Lactic acid production during the post-prandial period of the LGI trial was significantly higher than during the HGI trial. Such an induction of post-prandial lactic acid with LGI meals has been reported previously [9, 159]. Post-prandial lactate production is observed with meals high in fructose. The LGI meal was comprised of

lentils, which are low in fructose, but also integrated honey and Saskatoon berries. The fructose-fraction of carbohydrates in honey and Saskatoon berries is approximately 50 % [146, 168]. In comparison, potatoes contain only small amounts of fructose. The major metabolic pathway for fructose occurs hepatically, producing fructose-1-phosphate to be further metabolized to both glucose and lactate [169]. A transient increase in elevated post-prandial lactate during the LGI trial is likely due to the relative increase in fructose content of the pre-exercise meal.

During exercise, lactic acid levels during the first soccer match were similar between the two pre-exercise meals, but in the second match rose significantly higher during with the HGI meal than with the LGI meal. Accordingly, mean blood lactate levels during the first and second LGI matches were $4.4 \text{ mmol}\cdot\text{L}^{-1}$ and $3.2 \text{ mmol}\cdot\text{L}^{-1}$, respectively, while during the HGI matches levels stayed at $4.3 \text{ mmol}\cdot\text{L}^{-1}$ throughout both. Previous research on pre-exercise meal GI during steady-state cycling and running has shown similar reductions in blood lactate with LGI trials [5, 9, 14, 16, 126]. Lactate production is increased significantly during high intensity portions of soccer play, when anaerobic glycolysis is required to meet the high energy demands of the muscle [170]. The accumulation of lactate, as seen at the end of the soccer matches, increases when the lactate production in the muscle overcomes intracellular and lactate shuttle clearance [171]. Increased lactate accumulation has corresponded to lower level of muscle glycogen in previous research [126, 172]. High lactate levels observed during the HGI trial at the end of the second soccer match suggest muscle glycogen depletion was greater in comparison to the LGI trial.

4.2.4 Performance

Although pre-exercise LGI meals have caused alterations of substrate oxidation and conferred performance benefits [5, 6, 8, 49], this study found no differences in performance between the HGI and LGI pre-exercise meals. Performance similarities between trials may be due to the increased intensity of the exercise protocol in comparison to previous studies; resulting in high levels of participant fatigue. The RPE reported by participants was high during both trials, approximately 17 on a scale of 6 to 20, or ‘very hard’ (see also **Appendix 4**) [139]. The exercise protocol instigated a

decrease in carbohydrate oxidation and increased fat oxidation, over the course of both trials. While nutritional interventions are an important factor to consider in preserving performance; this protocol may have induced muscular fatigue that could not be overcome by nutritional intervention. Although the two meals were significantly different in digestive and absorptive properties, the near-equal CHO content of the meals was enough to meet requirements to affect performance equally [3].

4.2.5 Gastrointestinal symptoms

The second objective of this study was to determine the gastrointestinal symptoms experienced during the testing. Increased fullness and decreased hunger during the LGI trial, in conjunction with lower blood glucose response suggest delayed absorption of carbohydrates. As previously discussed, the amylopectin content of the LGI meal would have resulted in slower rates of digestion. Gastrointestinal upset has been reported in endurance athletes previously, most commonly in steady-state running exercise [173]. During exercise, significant reductions in gastrointestinal motility are generally observed above 70% of $\text{VO}_{2\text{max}}$ [174, 175]. Therefore, the running and sprinting segments of the simulated soccer match may have further influenced motility and absorption by decreasing peristalsis during high intensity sprinting in soccer.

A major anecdotal concern for this study is the fibre content of the LGI test meal. In the current investigation, adverse gastrointestinal symptoms of bloating, nausea or abdominal cramps were not reported in either trial group. While athletes are commonly advised to avoid gas-forming and fibre-rich foods before an event to evade gastrointestinal discomfort [3, 175], very few athletes are meeting even 50% of the RDA for fibre [71]. Such recommendations may not be supported by empirical evidence of the benefits of fibre consumption on gastrointestinal health. While increased soluble fibre content of regular diets may lead to a higher frequency of bowel movements, changes in weight or transit time of fecal discharge are not altered [176]. Increased dietary fibre intake promotes gastrointestinal adaptations including greater endothelial surface area resulting in faster fluid absorption and slower absorption of glucose [177]. Absorption is further enhanced in athletes with increased gastrointestinal perfusion, an adaptation to exercise training [175, 178]. Slower glucose absorption can lower the post-prandial blood

glucose response to a carbohydrate meal before and during exercise. Athletes should strive to consume higher quality diet and meet fibre requirements to improve gastrointestinal function to improve absorption and glucose delivery. Instead of focusing on the quantity of fibre in the diet, athletes may benefit from considering the source of fibre, as wheat and oat bran may contribute more fecal bulk than pea or other legume fibres [179]. Sports nutrition counseling can be further enhanced by recommendations including fibre intake, as this will meet the greater goals of improving performance and long-term health outcomes for current and retired athletes.

4.2.6 Questionnaire

The preliminary development of a questionnaire investigating athletes' beliefs and barriers to pulse-based meals revealed a number of interesting components. The use of a previously validated athletes' NKQ [80] proved effective in this population. The resulting overall score range of 22% and 86% would suggest the tool is effective within a university population who have completed a wide-range of nutrition training. Previous questionnaire validation studies suggest scores should range between 20 to 80% in order to avoid ceiling and floor effects [103, 180]. Furthermore, although the NKQ was previously administered to female athletes, there was no correlation between gender and score, supporting the use of this questionnaire in both genders. The high education level reported by this population may limit the application of this questionnaire to populations with lower education levels.

Participants most frequently reported consuming one serving of pulses per week. While there are no numerical recommendations for pulse consumption each week, the Canadian Food Guide recommends two to three servings of meats and alternatives each day and to "eat meat alternatives, such as beans, lentils, and tofu often" [181]. Thus, if individuals are to consume between 14 and 21 servings of meats per week, the results suggest only 32% of this sample are consuming a small percentage (5-7%) of servings of meats and alternatives as pulses.

Respondents disagree with barriers to pulse-based meal consumption. The highest rates of disagreement with barriers were related to will power, convenience, and food neophobia. Previous research in plant-based diets has also reported low barrier agreement

with this questioning method [100]. Agreement with barriers was most commonly related to practical knowledge. Such results are encouraging, as practical knowledge barriers can be addressed with community programs. Improving skills to prepare appealing meals and decreasing interpersonal barriers are good targets for subsequent strategies to improve consumption.

The attitudinal beliefs regarding pulse-based meal consumption revealed some points of concern and areas of future research. Athletes agreed with statements regarding the high nutrient density of pulse-based meals (i.e. increased fibre consumption), they did not agree with the potential health outcomes of consuming pulse-based meals (i.e. decrease my risk of disease in general). The beliefs regarding social and personal contentment were negatively correlated with the nutrient and health beliefs. As will be discussed in the limitations and future research section, the full impact of these correlations cannot be elucidated without a larger population with increased weekly pulse consumption.

Within the health belief model and diffusion of innovations model, individuals will act to increase a behaviour if the perceived benefits outweigh the barriers of that behaviour [92, 182]. The questionnaire responses indicate self-rated health among respondents is high, with over 75% of respondents rating their health as “very good” or “excellent”. If the health belief and diffusion of innovation models are applied appropriately, athletes who already express positive health status may not perceive the additional benefits of lentil consumption to the same extent as an individual ranking their health as “fair”. The strategies for this population may require a multifaceted approach to improving beliefs about pulse-based meal consumption and the personal benefits they may experience. Furthermore, athletes exhibit more self-efficacy over their non-athlete counterparts, which is also a clear indicator of initiation and commitment to change [183, 184]. Working with a group with high self-efficacy offers greater opportunity for increasing pulse consumption when barriers of practical skills and perceived benefits are removed.

4.2.7 Limitations and future research

4.2.7.1 Principle investigation

Though this study was performed using a previously validated treadmill soccer simulation, limitations to the protocol exist. The intensity of two soccer matches separated by a three hour break induced high levels of fatigue. While most of the players executed both matches at the same intensity, reducing the intensity of the second soccer match was necessary to ensure subjects were able to maintain adequate running technique to avoid injury. Time-motion analysis of field hockey players shows reduced speed and greater time spent standing and running compared to walking, jogging and sprinting in international tournament play, so reducing the intensity of the second match fell within externally valid criteria [114].

Including both male and female athletes in the study design also generated a number of issues which require comment. More female athletes had to drop out of the study due to knee injuries from extensive running on the treadmill. Female soccer players are more likely than men to attain a knee injury, specifically injury to the anterior cruciate ligament [185, 186]. Future research including greater external validity and female athletes would benefit from two alterations: (i) shorter work sessions representing non-elite soccer matches, by reducing the length of the match or accounting for substitutions made during a match and (ii) both shorter duration repeated sprint and skills tests. Implementing these changes would reduce the intensity of play and reduce the risk of knee injuries [185]. In turn, greater numbers of participants, including females, would provide greater statistical power to compare response to differences in GI between genders. Secondly, although hormone cycles within the menstrual cycle influence substrate metabolism, female subjects were not required to report the stage of menses within the study design. Thus, substrate oxidation may have been influenced by menstrual hormone fluctuations not accounted for in the data. On the other hand, substrate metabolism is similar between males and females at moderate to high intensity exercise when accounting for aerobic fitness and fat free mass between genders [187]. In general, variation in substrate metabolism at different stages of the menstrual cycle are not greater than those differenced observed between genders [122, 188, 189]. With no

significant differences noted between genders during statistical analysis, the higher exercise intensity and duration in the current protocol likely outweigh any metabolic differences between genders. Future research investigating the effects of gender on metabolic and performance outcomes with pre-exercise meals of different glycemic indices would contribute a great deal to this area of sports nutrition.

The performance testing criteria may be enhanced through previously validated soccer skills tests [118]. Though the one-minute maximal sprints have greater external validity than those previously utilized in pre-exercise meal GI testing, improving the external validity of the performance test will allow for greater application of results for teams. A key marker of intensity is blood lactate buildup. Elite soccer players tend to reach blood lactate levels between 5 to 6 mmol·L⁻¹ during a competitive match, with reported peak blood lactate levels of 7.9 mmol·L⁻¹ [131]. Mean blood lactate levels attained in the current investigation reached an average value of 4.3 mmol·L⁻¹ during the end of the second match and peaking at 7.9 mmol·L⁻¹ only during the HGI trial after sprint performance testing. Therefore, the sprint criteria in this protocol provided a valid simulation of the intensity at the end of a soccer match. Without sufficient data on the metabolic profiles in soccer tournament performance, further research is needed to identify an appropriate level of intensity and practical testing criteria.

The test meal of lentils can also be improved for future research. Although the pilot study for this experiment aimed to reduce the size of the pre-exercise meals, a number of issues with treatment compliance were still present as participants were unable to consume the full test meal. It is pragmatic to consider administering pre-exercise meals one hour before competition. The Dietitians of Canada, along with the American Dietetic Association, recommend consuming 1.0 g·kg bw⁻¹ of CHO one hour before exercise [3]. Thus, administering the pre-exercise meals closer to the time of exercise would allow for 33% reduction in meal size and still meet national recommendations. The sensory aspects of the meal can also be improved, either through the use of traditional lentil foods such as dal (cooked lentils in Indian cooking) or preparing a lentil-flour based bread for athletes to consume.

A second limitation of the test meals is that the macronutrient distribution in each test meal was not matched. While the LGI meal delivered 71, 22, and 4% CHO, protein, and fat, the HGI meal delivered 71, 11, and 18%, respectively. The difference in meals was expected, as the study was designed to test whole foods and not individual macronutrient components. The potential limitation of these treatments is the potential for protein or fat distribution to influence metabolic outcomes. Certainly the increase in fat content of the HGI meal would have also increased fat oxidation during the trial [54]. Muscle glycogen synthesis during the LGI trial may have been accelerated due to the increased protein content [64]. Even so, the metabolic outcomes between the trials should be interpreted cautiously.

Extending this study to investigate the influence of LGI and HGI meals on training adaptations would allow this framework to grow and apply to new areas of research in sports nutrition. Currently, no literature on the long term effects of LGI foods and training adaptations exists. The evidence presented in this study suggests no immediate performance benefit in response to acute consumption of lentils as a pre-exercise meal. The metabolic outcomes of these meals may or may not play a role in recovery and adaptation to exercise. A closer look at the known factors of diet and training adaptations reveal possible mechanism for metabolic changes. Reduced blood glucose and insulin response from pre-exercise meals may play an important role in triggering genetic adaptations to exercise and improving myocellular glycogen storage capacity [190]. Also, alterations in nutrition lead to alterations in transcription factors of metabolic genes [191]. Induction of transcription for GLUT 4, pyruvate dehydrogenase kinase 4, and peroxisome proliferator-activate receptor-gamma co-activator 1 (proteins important for enhancing muscle aerobic capacity) were measured with and without carbohydrate ingestion, showing glucose intake attenuated the production of these proteins [194]. Thus, the impacts of alterations in training diet GI may lead to a better understanding of the role of carbohydrates in diet and performance.

4.2.7.2 Questionnaire

Development of a questionnaire to test athletes' beliefs and barriers to pulse-based meal consumption can be enhanced for future development. The small sample size in this validation did not provide a sufficient range in pulse and lentil consumption. Two strategies should be implemented to overcome this limitation. Currently, two food frequency questions are being used to evaluate pulse and lentil consumption each week. The sensitivity of the food frequency questions can be improved by dissecting the pulse consumption question into subgroups of pulses to describe beans in market terms such as black beans, white beans, kidney beans, garden peas, chickpeas, soybeans and lentils, etc. Further detail can be offered to describing common pulse-based meals, such as lentil and bean soups and salads, bean and chickpea dips, chili prepared with beans, peanuts, as well as culturally specific options such as dal or Mexican meals prepared with beans. Refining the descriptive components of the food frequency questions may improve the respondent's understanding of the question and identification of familiar foods. A recently published food frequency questionnaire for legumes suggests this style of questioning is a fair estimate of a seven day food recall [193].

The second strategy to improve the questionnaire would be to deliver the questionnaire to a greater population with varying degrees of pulse consumption. Low numbers of pulse and lentil consumption observed in these results may have produced a floor effect within the data. Such effects limit statistical analyses because there are insufficient differences between respondents and leads to a type II statistical error [152]. All respondents reported omnivore (mixed meal) dietary habits. Athlete populations who practice vegetarianism to some degree (i.e. lacto-vegetarians, lacto-ovo vegetarians, vegans) could improve the spectrum of pulse consumption. Also, only a small fraction of respondents reported culturally-influenced dietary habits. A broader spectrum of dietary habits among respondents would increase the variety of foods consumed and potentially increase reported pulse-based meal consumption. Further data collection is warranted for this questionnaire to perform a principal factor analysis and validation of the questionnaire for larger populations.

CHAPTER 5

SUMMARY AND CONCLUSIONS

This study determined the effects of low GI, high protein pre-exercise meals on simulated soccer tournament performance. Using a previously-validated protocol, participants executed two 90-minute simulated soccer matches separated by a three hour break on two occasions, two hours after consuming low or high GI pre-exercise meals. The lentil-based, low GI meal provided a nutrient rich, slowly digestible carbohydrates based on North American recommendations for athletes. Performance, measured by five one-minute sprints at the end of each soccer match, was not different between the treatments. The low and high GI meals elicited unique metabolic profiles throughout the post-prandial period for blood glucose and blood lactate, as well as alterations to insulin and carbohydrate oxidation throughout exercise. Furthermore, a trend towards greater fat oxidation in the low GI trial was observed. The overall impact of these metabolic outcomes on performance in intermittent exercise remains unclear; however there is a potential gain for training and adaptation to exercise with improved metabolic profiles during exercise. Further research in sub-maximal intermittent exercise, and the influence of GI on gender differences, is necessary to further elucidate the role of GI in pre-exercise meals. In a broader context, the importance for athletes to practice good nutritional strategies throughout training to ensure body function and health cannot be overemphasized. Athletes should strive to include a range of foods, including lentils and other legumes, in their diet for current and future health outcomes.

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APPENDIX 1

Confirmation of ethical approval

A1.1 Ethical Approval for Pilot Study



UNIVERSITY OF
SASKATCHEWAN

Biomedical Research Ethics Board (Bio-REB)

Certificate of Approval

PRINCIPAL INVESTIGATOR
Philip D. Chilibeck

DEPARTMENT
Kinesiology

Bio #
08-76

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT
Department of Pharmacy and Nutrition
University of Saskatchewan
Saskatoon SK

SUB-INVESTIGATOR(S)
Gordon A. Zello

SPONSORING AGENCIES
SASKATCHEWAN PULSE GROWERS

TITLE
Determination of the Acceptability, Palatability, and Glycemic Index of a Lentil Based Meal

ORIGINAL REVIEW DATE
11-Apr-2008

APPROVED ON
28-Apr-2008

APPROVAL OF
Researcher's Summary (30-March-2008)
Research Participant Information and
Consent Form v.2 (28-April-2008)
Lentil Evaluation Scorecard
Pulse-based Meal Questionnaire
Demographic Information Questionnaire
Nutritional Knowledge Questionnaire

EXPIRY DATE
27-Apr-2009

Acknowledge Receipt of:
Justification of the request for demographic
information

Full Board Meeting ☐

Delegated Review ☒

CERTIFICATION

The study is acceptable on scientific and ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research study, and for ensuring that the authorized research is carried out according to governing law. This approval is valid for the specified period provided there is no change to the approved protocol or consent process.

FIRST TIME REVIEW AND CONTINUING APPROVAL

The University of Saskatchewan Biomedical Research Ethics Board reviews above minimal studies at a full-board (face-to-face) meeting. Any research classified as minimal risk is reviewed through the delegated (subcommittee) review process. The initial Certificate of Approval includes the approval period the REB has assigned to a study. The Status Report form must be submitted within one month prior to the assigned expiry date. The researcher shall indicate to the REB any specific requirements of the sponsoring organizations (e.g. requirement for full-board review and approval) for the continuing review process deemed necessary for that project. For more information visit http://www.usask.ca/research/ethics_review/.

REB ATTESTATION

In respect to clinical trials, the University of Saskatchewan Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations and carries out its functions in a manner consistent with Good Clinical Practices. This approval and the views of this REB have been documented in writing.

Michel Desautels, Ph.D., Chair
University of Saskatchewan
Biomedical Research Ethics Board

Please send all correspondence to:

Ethics Office
University of Saskatchewan
Room 302 Kirk Hall, 117 Science Place
Saskatoon SK S7N 5C8
Telephone: (306) 966-2975 Fax: (306) 966-2069

A1.2 Ethical Approval for Principle Investigation



UNIVERSITY OF
SASKATCHEWAN

Biomedical Research Ethics Board (Bio-REB)

Certificate of Approval

PRINCIPAL INVESTIGATOR

Philip D. Chilibeck

DEPARTMENT

Kinesiology

Bio #

08-77

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT

Department of Pharmacy and Nutrition	College of Kinesiology
University of Saskatchewan	105 Gymnasium Place
Saskatoon SK	Saskatoon SK S7N 5C2

SUB-INVESTIGATOR(S)

Gordon A. Zello

SPONSORING AGENCIES

SASKATCHEWAN PULSE GROWERS

TITLE: The Effect of Low and High Glycemic Index Meals on Metabolism and Performance During Consecutive Simulated Soccer Matches

ORIGINAL REVIEW DATE

21-Apr-2008

APPROVED ON

08-May-2008

APPROVAL OF

Researcher's Summary
Consent Form (version 2, 07-May-2008)
Appendix "A"
Recruitment Poster

EXPIRY DATE

07-May-2009

Full Board Meeting

Date of Full Board Meeting: 21-Apr-2008

Delegated Review

CERTIFICATION

The study is acceptable on scientific and ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research study, and for ensuring that the authorized research is carried out according to governing law. This approval is valid for the specified period provided there is no change to the approved protocol or consent process.

FIRST TIME REVIEW AND CONTINUING APPROVAL

The University of Saskatchewan Biomedical Research Ethics Board reviews above minimal studies at a full-board (face-to-face) meeting. Any research classified as minimal risk is reviewed through the delegated (subcommittee) review process. The initial Certificate of Approval includes the approval period the REB has assigned to a study. The Status Report form must be submitted within one month prior to the assigned expiry date. The researcher shall indicate to the REB any specific requirements of the sponsoring organizations (e.g. requirement for full-board review and approval) for the continuing review process deemed necessary for that project. For more information visit http://www.usask.ca/research/ethics_review/.

REB ATTESTATION

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Michel Desautel Ph.D., Chair
University of Saskatchewan
Biomedical Research Ethics Board

Please send all correspondence to:

Ethics Office
University of Saskatchewan
Room 302 Kirk Hall, 117 Science Place
Saskatoon SK S7N 5C8
Telephone: (306) 966-2975 Fax: (306) 966-2069

APPENDIX 2
Consent Forms

A2.1 Pilot study written consent form

Research Participant Information and Consent Form

Title: Determination of the acceptability, palatability, and glycemic index of a lentil-based meal.

Funding Agency: Saskatchewan Pulse Growers

Names of Researchers: Principal Investigator: Gordon Zello, Ph.D., College of Pharmacy and Nutrition, University of Saskatchewan, University of Saskatchewan, phone: 966-5825, Co-investigators: Christine Bennett, B.Sc. (student researcher, co-supervised by Gordon Zello and Phil Chilibeck), College of Pharmacy and Nutrition, University of Saskatchewan, phone: 966-2635, Philip Chilibeck, Ph.D., Albert Vandenberg, Ph.D., Department of Plant Sciences, University of Saskatchewan

Introduction: You are being invited to participate in a research study because we want to determine the acceptability, palatability, and glycemic index of a lentil based meal.

Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts.

If you wish to participate, you will be asked to sign this form. Your participation is entirely voluntary, so it is up to you to decide whether or not to take part in this study. If you do decide to take part in this study, you are free to withdraw at any time without giving any reasons for your decision and your refusal to participate will not affect your relationship with university instructors, your academic evaluations, or any other services at the university. Please take time to read the following information carefully and, if you choose, discuss it with your family, friends, and doctor before you decide.

Purpose of the study: The purpose of the study is to measure the glycemic (blood glucose) response, palatability, and acceptability of lentil-based meal. We have previously shown that a lentil-based meal is beneficial for sports performance, but lentils given on their own are not very enjoyable. In this study, we want to test a meal that might be more enjoyable.

Potential benefits: We hope to use this meal in the future to determine whether it is beneficial for endurance exercise and performance. This benefit is not guaranteed. There is no direct benefit to you for participating in this study.

Procedures:

If you agree to be in this study the following will happen:

Visit #1

You will be asked to come to the lab after a 10-hour overnight fast. Before coming, please do not do any vigorous activities or consume any alcohol on the day before the test. Before you consume the test meal, we will collect a small amount of blood from

your finger tip every 15 minutes. This involves using a “lancet” (a sterile sharp tip) to “prick” your finger so we can obtain a drop of blood to determine blood sugar (glucose) levels. We will also measure your height and body weight.

Next, you will be randomly assigned to consume one of two meals. One meal contains white bread and the other meal contains a combination of lentils, honey, and Saskatoon berries. The amount of each meal that you will be asked to consume will be based on the available carbohydrate that is in each serving.

Meal A: You will be asked to consume approximately 200 g of the lentil meal. During this meal you will be asked to answer a number of questions regarding the palatability and acceptability of the meal.

Meal B: approximately two slices of white bread.

You will have 15 minutes to consume the meal. We will then take a finger blood sample 15, 30, 45, 60, 90, and 120 minutes after consuming the meal.

Visit #2

At least 24 hours after visit number 1, you will come to the lab to do the exact same procedure. During this visit, you will be asked to consume the alternative meal that you did not consume on the first day.

We will ask you to fill out a number of questionnaires on your attitudes and beliefs towards lentils, and on your general nutrition knowledge. These questionnaires will take about a half an hour to fill out. These include questions on income, education and ethnicity because these factors are related to nutrition knowledge and consumption of lentils (i.e. lentils are popular in East Indian cuisine). All questions are optional. You do not have to answer any questions you are uncomfortable with.

Foreseeable risks, side effects or discomfort:

There may be some discomfort/pain during the drawing of blood. There is a risk of bruising and infection with the drawing of blood, but care will be taken to minimize these risks.

There may be unforeseen and unknown risks during the study, or after the study has been completed.

Research-Related Injury: There will be no cost to you for participation in this study. You will not be charged for any research procedures. In the event you become ill or injured as a result of participating in this study, necessary medical treatment will be made available at no additional cost to you. By signing this document you do not waive any of your legal rights. You will be compensated for your time commitment to the study, for travel to our lab, and parking expenses.

Confidentiality: While absolute confidentiality cannot be guaranteed, every effort will be made to ensure that the information you provide for this study is kept entirely confidential. Your name will not be attached to any information, nor mentioned in any study report, nor be made available to anyone except the research team. It is the intention of the research team to publish results of this research in scientific journals and to present the findings at related conferences and workshops, but your identity will not be revealed.

Voluntary Withdrawal: Your participation in this research is entirely voluntary. You may withdraw from this study at any time. If you decide to enter the study and to withdraw at any time in the future, there will be no penalty or loss of benefits to which you are otherwise entitled.

If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during your enrolment in the study will be retained for analysis.

Who to Contact for Questions or Concerns: If you have questions concerning the study you can contact Dr. Gordon Zello at 966-5825 or Christine Bennett (student researcher) at 966-2635.

If you have any questions about your rights as a research subject or concerns about this study, you should contact the Chair of the Biomedical Research Ethics Board, c/o the Office of Research Services, University of Saskatchewan at (306) 966-4053.

By signing below, I confirm the following:

- I have read this research subject information and consent form and I understand the contents of this form.
- I have had sufficient time to consider the information provided and to ask for advice if necessary.
- I have had the opportunity to ask questions and have had satisfactory responses to my questions.
- I understand that all of the information collected will be kept confidential and that the result will only be used for scientific objectives.
- I understand that my participation in this study is voluntary and that I am completely free to refuse to participate or to withdraw from this study at any time without changing in any way the quality of care that I receive. I understand that if I am a student a decision not to participate will not affect my academic evaluations.
- I understand that I am not waiving any of my legal rights as a result of signing this consent form.
- I understand that there is no guarantee that this study will provide any benefits to me (if applicable).
- I have read this form and I freely consent to participate in this study.
- I will receive a dated and signed copy of this form.
- I agree that my family physician can be contacted about my participation in this study:

_____Yes _____No

Participant's Name (printed): _____

Participant's Signature: _____ Date: _____

Name of Individual conducting the consent process
(printed): _____

Signature of Individual conducting the consent process: _____

Date: _____

A2.2 Physical Activity Readiness Questionnaire (PAR-Q)

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of <u>any other reason</u> why you should not do physical activity?

If
you
answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.

- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

DATE _____

SIGNATURE OF PARENT
or GUARDIAN (for participants under the age of majority) _____

WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.



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PAR-Q & YOU

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

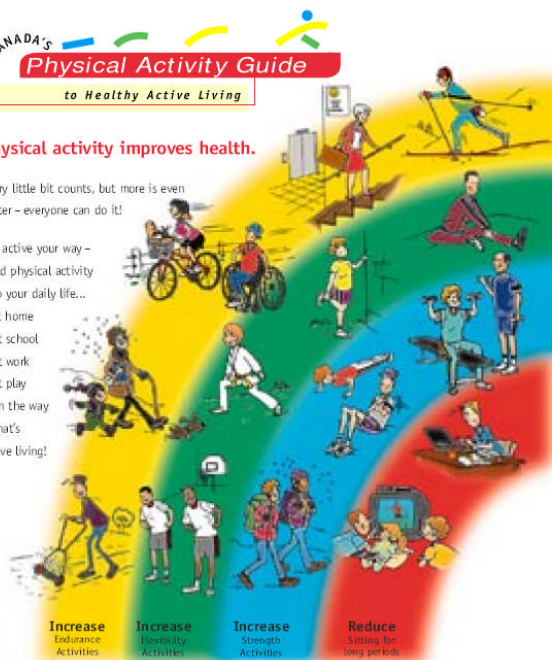


Physical activity improves health.

Every little bit counts, but more is even better – everyone can do it!

Get active your way – build physical activity into your daily life...

- at home
- at school
- at work
- at play
- on the way
- ...that's active living!



Increase
Endurance
Activities

Increase
Flexibility
Activities

Increase
Strength
Activities

Reduce
Sitting time
long periods

Choose a variety of activities from these three groups:

Endurance

4-7 days a week
Continuous activities for your heart, lungs and circulatory system.

Flexibility

4-7 days a week
Gentle stretching, bending and stretching activities to keep your muscles relaxed and joints mobile.

Strength

2-4 days a week
Activities against resistance to strengthen muscles and bones and improve posture.

Starting slowly is very safe for most people. Not sure? Consult your health professional.

For a copy of the Guide Handbook and more information:
1-888-334-9769, or
www.paguide.com

Eating well is also important. Follow Canada's Food Guide to Healthy Eating to make wise food choices.

Get Active Your Way, Every Day – For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add-up your activities in periods of at least 10 minutes each. Start slowly... and build up.

Time needed depends on effort				
Very Light Effort	Light Effort	Moderate Effort	Vigorous Effort	Maximum Effort
• Strolling • Dusting	60 minutes • Light walking • Volleyball • Easy gardening • Stretching	30-60 minutes • Brisk walking • Biking • Raking leaves • Swimming • Dancing • Water aerobics	20-30 minutes • Aerobics • Jogging • Hockey • Basketball • Fast swimming • Fast dancing	• Sprinting • Racing
Range needed to stay healthy				

You Can Do It – Getting started is easier than you think

Physical activity doesn't have to be very hard. Build physical activities into your daily routine.

- Walk whenever you can – get off the bus early, use the stairs instead of the elevator.
- Reduce inactivity for long periods, like watching TV.
- Get up from the couch and stretch and bend for a few minutes every hour.
- Play actively with your kids.
- Choose to walk, wheel or cycle for short trips.
- Start with a 10 minute walk – gradually increase the time.
- Find out about walking and cycling paths nearby and use them.
- Observe a physical activity class to see if you want to try it.
- Try one class to start – you don't have to make a long-term commitment.
- Do the activities you are doing now, more often.

Benefits of regular activity:

- better health
- improved fitness
- better posture and balance
- better self-esteem
- weight control
- stronger muscles and bones
- feeling more energetic
- relaxation and reduced stress
- continued independent living in later life

Health risks of inactivity:

- premature death
- heart disease
- obesity
- high blood pressure
- adult-onset diabetes
- osteoporosis
- stroke
- depression
- colon cancer



Source: Canada's Physical Activity Guide to Healthy Active Living, Health Canada, 1998 <http://www.hc-sc.gc.ca/hppb/paguide/pdf/guideEng.pdf>

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FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors' use by contacting the Canadian Society for Exercise Physiology (address below):

The **Physical Activity Readiness Medical Examination (PARmed-X)** – to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The **Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy)** – to be used by doctors with pregnant patients who wish to become more active.

References:

- Arraix, G.A., Wigle, D.T., Mao, Y. (1992). Risk Assessment of Physical Activity and Physical Fitness in the Canada Health Survey Follow-Up Study. *J. Clin. Epidemiol.* 45:4 419-428.
- Mottola, M., Wolfe, L.A. (1994). Active Living and Pregnancy. In: A. Quinney, L. Gauvin, T. Wall (eds.), **Toward Active Living: Proceedings of the International Conference on Physical Activity, Fitness and Health**. Champaign, IL: Human Kinetics.
- PAR-Q Validation Report, British Columbia Ministry of Health, 1978.
- Thomas, S., Reading, J., Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Can. J. Spt. Sci.* 17:4 338-345.

For more information, please contact the:

Canadian Society for Exercise Physiology
202-185 Somerset Street West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565
Online: www.csep.ca

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

Disponible en français sous le titre «Questionnaire sur l'aptitude à l'activité physique - Q-AAP (révisé 2002)».



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Supported by:



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A2.3 Principle investigation consent form

Research Participant Information and Consent Form

Title: The effect of low and high glycemic index meals on metabolism and performance during consecutive simulated soccer matches

Funding Agency: Saskatchewan Pulse Growers

Names of Researchers: Principal Investigator: Philip D. Chilibeck, Ph.D., College of Kinesiology, University of Saskatchewan, phone: 966-1072 or 343-6577, Co-investigators: Christine Bennett, B.Sc. (student researcher, co-supervised by Gordon Zello and Phil Chilibeck), College of Pharmacy and Nutrition, University of Saskatchewan, phone: 966-2635, Gordon Zello, Ph.D., College of Pharmacy and Nutrition, University of Saskatchewan, Albert Vandenberg, Ph.D., Department of Plant Sciences, University of Saskatchewan

Introduction: You are being invited to participate in a research study because we want to compare the effectiveness of consuming carbohydrate meals that differ in the rate at which they are digested (i.e. slow-digesting lentils versus fast-digesting mashed potatoes) on running performance that simulates two consecutive soccer games separated by a three hour break.

Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts. If you wish to participate, you will be asked to sign this form. Your participation is entirely voluntary, so it is up to you to decide whether or not to take part in this study. If you do decide to take part in this study, you are free to withdraw at any time without giving any reasons for your decision and your refusal to participate will not affect your relationship with university instructors, your academic evaluations, or any other services at the university. Please take time to read the following information carefully and, if you choose, discuss it with your family, friends, and doctor before you decide.

Purpose of the study: The purpose of the study is to compare the effectiveness of a lentil meal (i.e. boiled lentils) to mashed potatoes for improving running performance that simulates soccer tournament play. A treadmill will be used to simulate two consecutive soccer matches, with a three hour break in between. Lentils are digested more slowly in the body than potatoes and therefore may provide energy to your exercising muscles for a longer period of time. In our study we will be comparing a lentil-based meal (lentils with honey and Saskatoon berries) to a meal of potatoes and ketchup consumed before treadmill running tests designed to simulate a soccer match.

A total of 18-25 participants will be involved in this study.

Possible benefits of the study: Information from this study can be used by soccer players and coaches to increase endurance performance during soccer matches. These benefits are not guaranteed.

Procedures:

If you agree to be in this study the following will happen:

You will initially be given a questionnaire (the physical activity readiness questionnaire) which assesses whether you are at a health risk from participating in exercise. If there are possible health risks, with your permission we will send an additional form to your family physician for approval to allow you to participate in the study.

The study involves a total of 5 visits to our lab. The procedures to be done at each visit are as follows:

Visit #1:

You will have your maximal aerobic capacity determined on a treadmill test. This test determines your aerobic fitness. The length of this test can vary from about six minutes to 15 minutes, depending on your level of physical fitness. The test begins with running at an easy pace on the treadmill. The treadmill's speed is increased every minute (i.e. the treadmill keeps speeding up so that you have to run faster). This is done until you reach exhaustion. During this test you will be breathing through a mouthpiece connected to a computer that measures your maximal oxygen consumption. The maximal oxygen consumption is used to determine your level of physical fitness.

During visit number 1 you will be asked to fill out a questionnaire on current nutrition knowledge, physical activity knowledge, beliefs and barriers towards nutrition, and demographic information.

Visit #2:

Within one week of doing your treadmill test, you will come to the lab to perform a "practice meal" of the lentils. You will be required to fast for at least eight hours prior to visit number 2. For three days prior to visit number 2 you will be required to keep a diary of all the food you consume and the amount of physical activity you perform. After an eight hour fast, you will consume ~150g (2 g for every kg of your body weight) of the meal in our lab.

During visit number 2 you will be asked to fill out a questionnaire about acceptability of the meal and gut fullness after the meal was consumed.

Visit #3:

At least 24 hours after visit number 1, you will perform a “practice run” of the simulated soccer match on the treadmill. The speeds on the treadmill will vary to match the speeds you run/jog/walk during a soccer match. This will involve 5-10 second intervals of running alternating with 60 to 120 second intervals of walking or jogging. These intervals will be alternated for 45 minutes (simulating the first half of a soccer game). You will then be given a 15-minute break (simulating a half time break in a soccer game). After the break, you will continue doing the treadmill exercise (i.e. alternating intervals of running with walking/jogging) for 30 minutes. The final 15 minutes of the treadmill test will involve five 1-minute sprints, each separated by 2.5 minutes of walking at your own pace and we will measure the amount of “distance” you cover. You should attempt to go at the fastest pace you can go during these sprints.

Visit #4:

At least one week after visit #3, you will return to the lab for visit #4. You will be required to fast for at least eight hours prior to visit #4. For two days prior to visit #4 you will be required to keep a diary of all the food you consume and the amount of physical activity you perform.

For this visit you will be randomized (by chance by a computer) to one of two meal conditions: 1) the lentil-based meal; or 2) the potato-based meal.

After an eight hour fast, you will consume ~150 grams (2 g for every kg of your body weight) of the meal in our lab. After two hours you will perform the exact simulated soccer match on the treadmill that you performed during visit #3. You will be allowed to consume as much water as you wish during this test. After this test you will have a three hour break. During this time you will be provided with ~115g (1.5 g for every kg of body weight) of the meal that you must consume within the hour after the first treadmill test. For the following two hours you will rest in the lab. You will be allowed to drink as much water as you want during this 3 hour period. Three hours after completing the first treadmill test, you will start the second test. The second test will be exactly the same as the first test. Throughout both soccer matches you will be allowed to consume as much water as you want.

Prior to each treadmill test, the following measures will be taken:

- Prior to consuming the meal and just before the soccer match, your body weight will be taken.
- During the two-hour period after you consume the meal before each treadmill test, we will collect a small amount of blood from your finger tip every 15-60 minutes. This involves using a “lancet” (a sterile sharp tip) to “prick” your finger so we can obtain a drop of blood to determine blood sugar (glucose) levels. The exact time points this measurement will be taken are indicated in Table 1.

During each of the two treadmill tests, the following measurements will be made:

- Blood samples will be collected from your finger tip (i.e. single drops each time). This will be done at the start of the test, and at 15, 45, 90, and 105 minutes of the test (see Table 1). The purpose of the blood collection is to measure your blood sugar levels.
- 5-mL blood samples will be taken from a needle inserted into a vein in your forearm before starting each soccer match, and at 15, 45, and 105 minutes of each match (see Table 1). These samples will be used to determine your insulin and fat levels during the match. Insulin is a hormone released after a meal that affects fat and carbohydrate metabolism.
- You will be required to breathe into a mouthpiece that feeds into a tube connected to a computer for 7-minute periods at 3, 33, and 63 minutes of the test (see Table 1). The gases that we collect during this test (i.e. the oxygen you consume and the carbon dioxide you exhale) will be used to estimate the proportion of fat and carbohydrate your muscles are using during the exercise test.
- Every 15 minutes during the exercise test you will be asked to rate how the exercise feels on a scale of one to twenty, with “one” being “easy” and “twenty” being “very hard”. You will also be asked how full your stomach feels on a scale of zero to four, with “zero” being “no symptoms” and four being “severe symptoms”.

Table 1 summarizes the measurements that will be done before and during the simulated soccer matches. Note that these measurements apply to both soccer matches, which will be separate by 3 hours.

Table 1.

	Time (minutes)														
	Pre-exercise				First Half					Half-time	Second Half				
Measure	-120	-105	-90	-60	0	3-10	15	30	33-40	45-60	63-70	75	90	90-105	105
Finger tip blood sample (glucose and lactate)	X	X	X	X	X		X			X			X		X
Meal consumption completed	X														
Blood sample from forearm vein (fat, insulin)					X		X			X					X
Expired gas collection						X			X		X				
RPE							X	X		X		X	X		X
Repeated Sprint Test														X	

Visit #5

At least one week after visit #4, you will come back to the lab for a repeat of the testing described for visit #4, but this visit will involve a different meal condition (i.e. whichever meal condition you did not consume in visit #4). For two days before this visit, you will be required to consume the same foods and perform the same physical activities you recorded during the two days prior to visit #4. During the treadmill test you will be given the same amount of water that you consumed during the treadmill test you performed at visit #4.

Foreseeable risks, side effects or discomfort:

The exercise may result in muscle pulls or strains. You will be given a proper warm-up prior to exercising and this will minimize this risk and all exercise tests will be administered by qualified exercise trainers. If any serious pulls or strains occur, you will be withdrawn from the study.

There may be some discomfort/pain during the drawing of blood. There is a risk of bruising and infection with the drawing of blood, but care will be taken to minimize these risks.

You may experience fatigue during the exercise tests, because these are long in duration.

You may experience digestive problems (i.e. upset stomach, nausea, indigestion) from the meals. In a previous study using a single soccer match no subject had to stop testing because of digestive problems.

There may be unforeseen and unknown risks during the study, or after the study has been completed.

Research-Related Injury: There will be no cost to you for participation in this study. You will not be charged for any research procedures. In the event you become ill or injured as a result of participating in this study, necessary medical treatment will be made available at no additional cost to you. By signing this document you do not waive any of your legal rights. You will be compensated for your time commitment to the study, for travel to our lab, and parking expenses.

Confidentiality: While absolute confidentiality cannot be guaranteed, every effort will be made to ensure that the information you provide for this study is kept entirely confidential. Your name will not be attached to any information, nor mentioned in any study report, nor be made available to anyone except the research team. It is the intention of the research team to publish results of this research in scientific journals and to present the findings at related conferences and workshops, but your identity will not be revealed. Because of the intense exercise involved in the study, we are asking your permission to contact your family physician about your participation in the study.

Voluntary Withdrawal: Your participation in this research is entirely voluntary. You may withdraw from this study at any time. If you decide to enter the study and to withdraw at any time in the future, there will be no penalty or loss of benefits to which you are otherwise entitled.

If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during your enrolment in the study will be retained for analysis.

Who to Contact for Questions or Concerns: If you have questions concerning the study you can contact Dr. Philip Chilibeck at 966-1072, 343-6577, or 230-3849 (24 hour cell) or Christine Bennett (student researcher) at 966- 2635.

If you have any questions about your rights as a research subject or concerns about this study, you should contact the Chair of the Biomedical Research Ethics Board, c/o the Research Ethics Office, University of Saskatchewan at (306) 966-4053.

By signing below, I confirm the following:

- I have read this research subject information and consent form and I understand the contents of this form.
- I have had sufficient time to consider the information provided and to ask for advice if necessary.
- I have had the opportunity to ask questions and have had satisfactory responses to my questions.
- I understand that all of the information collected will be kept confidential and that the result will only be used for scientific objectives.
- I understand that my participation in this study is voluntary and that I am completely free to refuse to participate or to withdraw from this study at any time without changing in any way the quality of care that I receive. I understand that if I am a student a decision not to participate will not affect my academic evaluations.
- I understand that I am not waiving any of my legal rights as a result of signing this consent form.
- I understand that there is no guarantee that this study will provide any benefits to me.
- I have read this form and I freely consent to participate in this study.
- I will receive a dated and signed copy of this form.
- I agree that my family physician can be contacted about my participation in this study:

_____Yes _____No OR I do not have a family physician

Participant's Name (printed): _____

Participant's Signature: _____ Date: _____

Name of Individual conducting the consent process
(printed): _____

Signature of Individual conducting the consent process: _____

Date: _____

APPENDIX 3

Determination of the acceptability, palatability, and glycemic index of a lentil based meal: a pilot study

A3.1 Introduction

Previous studies investigating athletic performance and GI have used a variety of diet protocols, ranging from single foods, such as lentils, to complete meals with predicted glycemic indices [6, 12, 15]. The external application of these treatments for athlete dietary consumption is therefore variable. Previous research carried out at the University of Saskatchewan identified that soccer players were resistant when asked to consume a lentil-based meal prior to exercise [50, 61]. Based on the CHO content of lentils, providing 1.5 to 2.0 g·kg bw⁻¹ would require a 70-kg athlete to consume approximately three cups of cooked lentils. A pilot project was therefore developed to reduce the volume of a pre-exercise lentil meal while maintaining the low glycemic response. The anticipated goal of this project was to measure a positive overall liking of the test meal after the addition of fruit, honey, and cinnamon. With the addition of such ingredients, it was important to maintain a glycemic response corresponding to the consumption of low glycemic index (GI) foods. While glycemic index is used to describe the relative glycemic response of single food items, it cannot be directly applied to mixed meals. For this reason, the test meals are described based on their mixed meal glycemic response.

A3.2 Objective and hypothesis

The objective was to develop a low glycemic response, lentil-based meal with improved acceptability and palatability to improve likelihood of consuming this food prior to exercise. It is hypothesized that the glycemic response to the lentil based meal will be significantly lower than the control white bread meal. More specifically, the glycemic response would correspond to a low GI, with a score less than 50 compared to the white bread sample. The pilot study could also be used to develop a meal that could be consumed to supply Canadian athletes with sufficient carbohydrates meeting the recommendations from the Dietitians of Canada [3].

A3.3 Methods

A3.3.1 Subjects

Ten participants (three males, seven females) completed the pilot study. The average weight of the participants was 80.2 ± 4.3 kg and 67.4 ± 8.6 kg for males and females, respectively. Four participants reported participating in regular physical training. Inclusion criteria were based on normal gastrointestinal function and non-diabetic status. Fully informed consent was obtained from each subject and the study design was approved by the University Of Saskatchewan Biomedical Research Ethics Board (Bio # 08-76).

A3.3.2 Experimental Design

Subjects reported to the laboratory after a 12-hour fast to consume the lentil-based test meal followed by a white bread control meal on two occasions, separated by at least 48 hours. Subjects were advised to avoid physical activity prior to reporting to the laboratory. On the first day of testing, subjects were weighed and provided with a meal size based on recommended CHO consumption two hours prior to exercise ($2.0 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$, Table 2). On the second day of testing, participants consumed a white bread sample also based on $2.0 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$ of available CHO. The meals were delivered in non-random order to ensure that participants were able to consume the full size of the lentil meal prior to consuming the bread meal of the same size.

Table A3.1: Pilot study test meal composition for 70-kg athlete.

Meal	Ingredients	Volume (mL)	Weight (g)	CHO _a (g)	Protein (g)	GI	Fibre (g)	Energy (kcal)
LGI	Red Lentils	500	418	84	38	26	18	486
	Honey	30	42	36	0	87	0	130
	Saskatoon Berries	250	148	19	1	50 ₁	4	84
	TOTAL	780	586	140	39	36 ₂	22	700
Control	White Bread	--	269	140	22	70 ₂	5	718
Macronutrient data provided by manufacturers information and cross referenced with Canadian Nutrient File Data. * 1 - Estimate based on blueberry data. 2. Meal GI compared to bolus of glucose [152].								

A3.2.3 Glycemic response testing

Previously validated glycemic response testing was based on GI methodology described by Jenkins et al. [4]. On both test days, capillary finger-tip blood samples were obtained from subjects at fasting and at 15, 30, 45, 60, 90, and 120 minutes after the consumption of the test meal. Glycemic response was measured by commercial blood glucose meters (Accu-check Compact Plus, Roche Diagnostics, Mannheim, Germany).

A3.2.4 Questionnaires

A food acceptability and palatability scorecard was presented to the participants within the first five minutes of beginning pre-exercise meal consumption (**Appendix 6**). Areas of sensory analysis included appearance, texture, taste, sweetness, and likelihood to consume. All responses were measured using a seven-point Likert scale. A five-point “just about right” scale (1= not at all sweet enough; 3= just about right; 5=far too sweet) was used to evaluate the appropriateness of the sweetness of the meal [196]. Subjects also completed a questionnaire investigating beliefs and barriers to pulse-based meals consumption, demographics information, and a nutritional knowledge questionnaire (**Appendix 5**).

A3.2.5 Data analysis

Results from blood glucose testing for the test meal and the white bread meal were used to geometrically calculate the incremental area under the curve (AUC) in accordance with Wolever and Jenkins [152] by which area under the baseline are excluded (Equation 1.1).

$$GR_{test\ meal} = \frac{AUC_{test\ meal}}{AUC_{white\ bread}} = \frac{(A+B+C+\frac{D}{2})t+D^2t/(D+|E|)}{(A+B+C+\frac{D}{2})t+D^2t/(D+|E|)} \quad (1.1)$$

Where A , B , C , D and E represent positive (compared to baseline) blood glucose increments in units of mmol/L, t is the time interval between increment in units of minutes. $|E|$ represents the absolute value of E is used if E is below baseline (time point A) [197].

AUC values were then used to determine the relative glycemic response of the test meal that could be compared with the weighted average of the glycemic indices of the test meal components.

The volume of test meal consumed was then used to determine the optimal serving of food that could be provided to the participants during the principle investigation.

Statistics: Pairwise differences for incremental glycemia at each time point (15,30,45,60,90 and 120 minutes) between the treatments were assessed by repeated measures ANOVA. When significance was noted, Tukey's least significant difference was used to identify which means differed. Sensory evaluation results are reported as frequencies. All results are described as mean \pm standard deviation (SD) and considered statistically significant if $P < 0.05$.

A3.3 Results

A3.3.1 Meal Consumption

Most participants were unable to consume the full serving size of $2.0 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$ within the 25-minute timeframe. On average, participants were able to consume 69.0 ± 17.6 per cent of the meal, or $1.38 \pm 0.35 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$. Based on these consumption results, the available carbohydrates of the white bread samples were adjusted to match the available carbohydrates consumed during the lentil meal.

A3.3.2 Blood Glucose Response

A significant main effect of meal consumed on blood glucose response ($F=17.7$, $p < 0.001$, **Figure A3.1**). The resulting AUC for the lentil-based meal and matched white bread sample was 59.71 ± 25.4 and 154.8 ± 94.3 , respectively. Based on AUC, the mean relative glycemic response was 42.5 ± 15.6 .

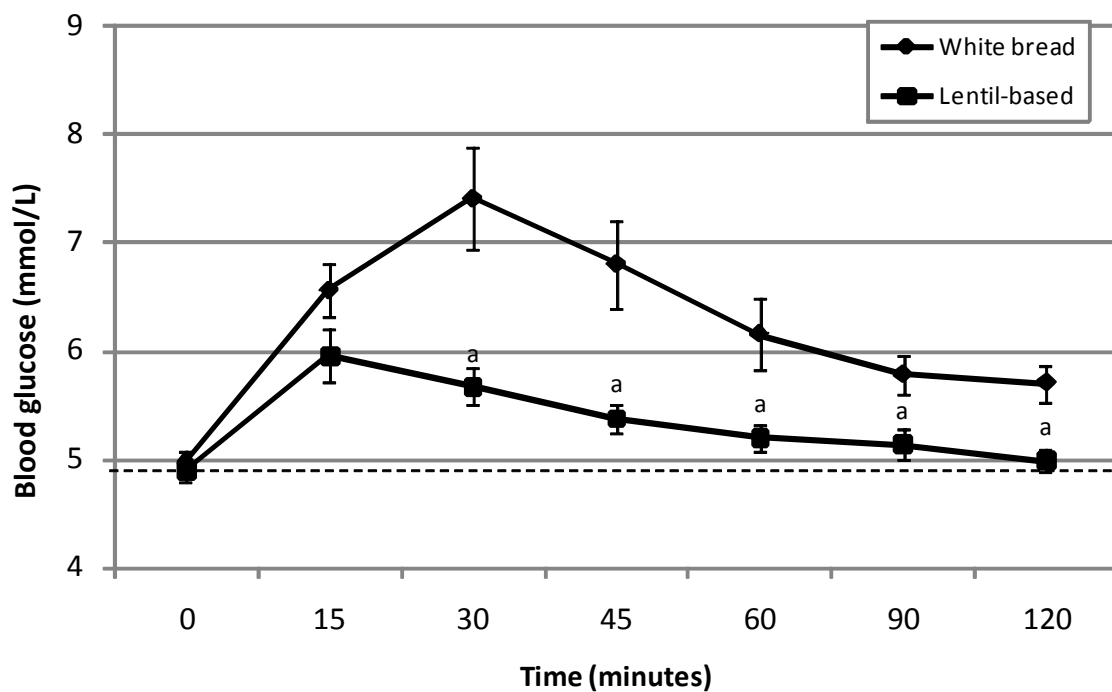


Figure A3.1: Mean incremental blood glucose response for the lentil based meal and white bread (control). Data are expressed as mean \pm SE. Dashed line represents mean baseline blood glucose response ($4.93 \text{ mmol}\cdot\text{L}^{-1}$). Significance is noted as (a) lentil-based meal was significantly different from control.

A3.3.3 Sensory Analysis

Responses to the sensory analysis questionnaire were reduced into categories of “dislike”, “don’t know” or “like”. For ratings of appearance, 40% of responses were dislike, while 40% “like”. Secondly, 54 per cent of respondents reported they disliked the flavor and texture of the test meal. For perceived sweetness of the test meal, 54 per cent said they liked the sweetness of the meal. Finally, when questioned on their general opinion of the test meal, 50% reported they liked the test meal. On a five point “just about right” scale, 36 % of respondents said they thought the test meal was “just about right” for sweetness, while 50% of respondents said they thought the sweetness was “not sweet enough”.

A3.4 Discussion

The principle outcome for the pilot study demonstrated, as hypothesized, blood glucose response to the lentil-based meal as low in comparison to the white bread control meal. A relative mixed meal glycemic response, 42 ± 15 was comparable to the calculated GI of 43.5, categorizing the meal as low GI. Such results corroborate previous findings which compare measured and predicted GI values [197]. These preliminary pilot study results were incorporated, as modifications, to the procedures used in the main study.

Further results demonstrated a significant inability to consume the proposed test meal. Though the full meal ($2.0 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$) was only consumed on 2 of 10 occasions, the mean consumption rate of $1.4 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$ and a median consumption of $1.5 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$. A major concern for this study was including non-athlete individuals, considering that athletes are known to consume more food and calories in a single sitting than inactive individuals [198]. A number of studies have used pre-exercise meal servings of $1.5 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$ [6, 8]. Based on: (i) the pilot study results of meal intake, (ii) consideration that athletes consume larger amounts of food than non-athletes [69], and (iii) complementary methods in previous research, the principle study went forward using $1.5 \text{ g} \cdot \text{kg} \text{ bw}^{-1}$ as the test meal size.

Sensory analysis during testing showed generally negative attitudes towards the test meal, with texture and appearance rated lowest. In interpreting these results,

consideration was given to the types of ingredients that would improve the palatability of the meal, after informal analysis of meals using alternative spice combinations, it was recognized that additional ingredients could not be added to the test meal without increasing the glycemic response. Many subjects reported never consuming pulses or lentils, and only two of ten participants consumed lentils once a week. Food preferences developed during childhood are a driving factor for food preferences during adulthood, suggesting that liking new foods is often based on previous experiences [199]. Sensory preference for foods, particularly taste, is developed in childhood and formative years, when perceptions of taste are strongest [198]. In North American cultures, childhood exposure to pulses is often limited, and thus adult enjoyment may be limited as a result. Other limiting factors for increased consumption of meat alternatives are time and food preparation knowledge [199]. As only two participants in this study reported consuming lentils once a week, a lack of acceptance of the test meal may be due to a lack of previous exposure caused by any number of factors. Based on the glycemic response of the test meal and the known limitations for lentil consumption for adults, the principle study was initiated with modified pre-exercise test meals.

APPENDIX 4

Borg perceived exertion scale

Exertion	RPE
no exertion at all	6
extremely light	7
	8
very light	9
	10
light	11
	12
somewhat hard	13
	14
hard (heavy)	15
	16
very hard	17
	18
extremely hard	19
maximal exertion	20
From Borg [141]	

APPENDIX 5

Questionnaire: Nutritional knowledge and attitudes towards pulse-based meal consumption

Questionnaire:
Nutritional knowledge and attitudes towards
pulse-based meal consumption

University of Saskatchewan
2008

Pulses, also referred to as legumes, are seeds of plants. These include beans (kidney beans, white beans, black beans, navy beans), soy beans, chickpeas, peas (i.e split peas), and lentils (red, yellow, and green).

Part 1:

As part of your participation in this study, we ask that you fill out this questionnaire to help us better understand your attitudes about consuming pulse-based meals. Please answer all of the questions in this section.

1. Some people believe that eating pulses (i.e Lentils) has specific difficulties. How much, if at all, do these statements apply to you? (Please circle one answer for each of the statements)

I believe that eating pulse-based meals is difficult because:

	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
I need more information about pulses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't want to change my eating habit or routine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
My family/partner won't eat a meal containing pulses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pulse-based meals or snacks are not available when I eat out	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I'm too busy to prepare a pulse-based meal, I need something that's easier to consume on the run	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't have enough willpower	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Someone else decides most of the foods that I eat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It would be too expensive	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't want to eat strange or unusual foods	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would have to go shopping too often	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There's not enough protein in them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would get indigestion, bloating, gas or flatulence	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It would not be filling enough	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
There is not enough iron in them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't know how to prepare pulse-based meals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I wouldn't get enough energy or strength	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It would not be tasty enough	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It is inconvenient	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would need to eat such a large quantity of food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It takes too long to prepare a pulse-based meal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Someone else prepares my meals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't want people to think I'm strange or a hippy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. Some people believe that eating pulses (i.e Lentils) has specific benefits. How much, if at all, do these statements apply to you? (Please circle one answer for each of the statements)

	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
I believe that pulse-based meals can help decrease my saturated fat intake	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals have lots of fibre	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals help me to improve my energy levels throughout the day	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals have lots of vitamins and minerals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals help prevent disease in general (e.g. heart disease, diabetes)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that a pulse-based meals help me to improve my digestion	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals could help me to eat a greater variety of foods	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals are a good source of protein	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals could help me to stay healthy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that a pulse-based meals can help me to have a better quality of life	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that a pulse-based meals can help me to control my weight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that a pulse-based meals can help me to be fit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals can be a part of a tasty diet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals can help the environment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals can help me to save money	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals can help me to be more content with myself	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe that pulse-based meals can help me to look more 'trendy' to my friends	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Part 2: Demographic Information

1. What is your gender?
 - ☐ Male
 - ☐ Female
2. What is your age? _____
3. Which of the following best describes your employment status at this time?
 - ☐ Full time employment
 - ☐ Part time employment
 - ☐ Student with full time employment
 - ☐ Student with part time employment
 - ☐ Student with part time employment during the academic year
 - ☐ Student
 - ☐ Unemployed
4. What is the highest level of education that you have completed?
 - ☐ Some high school
 - ☐ Completed high school
 - ☐ Some community college/technical institute
 - ☐ Completed community college/technical institute
 - ☐ Some university
 - ☐ Completed university (undergraduate degree)
 - ☐ Some graduate studies
 - ☐ Completed graduate degree
5. Which of the following categories best describes your household total gross annual income?
 - ☐ \$0-\$9,999
 - ☐ \$10,000-\$19,999
 - ☐ \$20,000-\$29,999
 - ☐ \$30,000-\$39,999
 - ☐ \$40,000-\$49,999
 - ☐ \$50,000-\$59,999
 - ☐ \$60,000-\$69,999
 - ☐ \$70,000-\$79,999
 - ☐ \$80,000 and over
6. How many persons are living in your household (including yourself)? _____
7. What are the ages of these persons? _____
8. Which of the following best describes your formal nutrition training?

- ☐ Do not have any
- ☐ High school course
- ☐ College and/or university course
- ☐ Other, please state: _____

Current Dietary practices:

9. How would you describe your dietary practices

- ☐ Vegetarian
- ☐ Lacto-vegetarian
- ☐ Lacto-ovo-vegetarian
- ☐ Vegan
- ☐ Mixed diet (consumes foods from all four food groups)

10. Are your food habits influenced by your cultural or ethnic background?

- ☐ Yes ☐ No

11. To which ethnic or cultural group(s) do you belong?

12. How many times per week to you consume pulses?

- ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

13. How many times per week to you consume lentils?

- ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Physical Activity:

14. How many exercise sessions do you have in a week?

- ☐ 0-1 ☐ 2-4 ☐ 5-7 ☐ >7

15. What is the average duration of your exercise session?

- ☐ 0-10 minutes
- ☐ 11-20 minutes
- ☐ 21-40 minutes
- ☐ 41-60 minutes

- ☐ 61-90 minutes
- ☐ 91-120 minutes
- ☐ >120 minutes

16. What is your typical pre-exercise meal: size and composition?

General Health:

17. Do you participate in any of these health conscious activities? Please indicate all applicable choices:

- ☐ Nutritional label reading
- ☐ Watching fat intake
- ☐ Monitoring fast food meals each week
- ☐ Monitoring candy or snack foods each week
- ☐ Eat at least 5 servings of fruits and vegetables each day
- ☐ Dietary supplementation with vitamins and minerals
- ☐ Other, please

specify: _____

18. In general, would you say your health is:

- ☐ Excellent
- ☐ Very good
- ☐ Good
- ☐ Fair
- ☐ Poor

PART 3 – Nutritional Knowledge

For each question, please pick the number that best describes your answer:

1 = Strongly Disagree

2 = Disagree

3 = Undecided

4 = Agree

5 = Strongly Agree

		SD	D	U	A	SA
1	An equivalent weight of carbohydrate and protein have approximately the same caloric value	1	2	3	4	5
2	Carbohydrates are not as easily and rapidly digested as protein and fat	1	2	3	4	5
3	A slice of bread is an example of 1 serving from the bread and cereals food group	1	2	3	4	5
4	Honey contains fewer calories than an equal amount of sugar	1	2	3	4	5
5	Foods such as potatoes and honey are best eaten after exercise	1	2	3	4	5
6	Eggs and legumes are examples of protein sources other than meat	1	2	3	4	5
7	Protein is the primary source of muscular energy for the athlete	1	2	3	4	5
8	Protein is not stored in the body; therefore, it needs to be consumed every day	1	2	3	4	5
9	All red meat is high in saturated fat	1	2	3	4	5
10	No more than 15% of calories in the diet should be provided by fat	1	2	3	4	5
11	Substitution of polyunsaturated fat for some saturated fat is recommended to lower the risk of heart disease	1	2	3	4	5
12	Adequate fat intake is necessary for estrogen production	1	2	3	4	5
13	Broccoli is a plant source of calcium	1	2	3	4	5
14	Milk is a good supplier of calcium of all age groups	1	2	3	4	5
15	800 milligrams of calcium per day is the recommended dietary allowance (RDA) for females aged 15-24	1	2	3	4	5
16	Adequate calcium intake is necessary for female athletes of all ages to prevent osteoporosis	1	2	3	4	5
17	Two 8-ounce glasses of milk is enough to fulfill the recommended amount of calcium per day	1	2	3	4	5
18	Carbonated beverages can negatively affect calcium metabolism	1	2	3	4	5
19	Iron-deficiency anemia results in a decrease in the amount of	1	2	3	4	5

	oxygen that can be carried in the blood					
20	Cheese is a good source of iron in the diet	1	2	3	4	5
21	Those with a meatless diet are at a higher risk of iron deficiency	1	2	3	4	5
22	Iron in meat is absorbed at the same rate as iron in a plant food	1	2	3	4	5
23	Due to menstruation, females need more iron in their diets than men	1	2	3	4	5
24	A lack of iron in the diet can result in fatigue, injury, and illness	1	2	3	4	5
25	Meat and eggs are good sources of zinc	1	2	3	4	5
26	Bananas and avocados are good sources of potassium	1	2	3	4	5
27	Vitamin supplementation is recommended for all physically active people	1	2	3	4	5
28	Excess vitamin supplementation may harm the physically active person	1	2	3	4	5
29	Vitamins in mineral-enriched foods are not used by the body as well as naturally occurring vitamins	1	2	3	4	5
30	Vitamins are a good source of energy	1	2	3	4	5
31	Green, leafy, and yellow vegetables are important because they help ensure the vitamin A requirement for the individual	1	2	3	4	5
32	Carrots are a good source of vitamin A	1	2	3	4	5
33	Whole milk is a better source of vitamin D than skim or 2% milk	1	2	3	4	5
34	The body can synthesize vitamin D upon exposure to the sun	1	2	3	4	5
35	Potatoes, strawberries and cantaloupe are good sources of vitamin C	1	2	3	4	5
36	The best sources of folic acid are supplemented grain products and fortified breakfast cereals	1	2	3	4	5
37	Vitamin E is required for blood clotting	1	2	3	4	5
38	Salt is an essential part of a healthy diet	1	2	3	4	5
39	Fibre in the diet may help to decrease constipation, decrease blood cholesterol levels, and prevent cancers	1	2	3	4	5
40	Bread and cereals is the only food group that is a good source of fibre	1	2	3	4	5
41	Two servings of vegetables per day fulfills recommended dietary allowances	1	2	3	4	5
42	Dark-colored vegetables have more nutritional value than pale vegetables	1	2	3	4	5
43	Fresh, frozen, and canned vegetables all have similar nutrient values	1	2	3	4	5
44	Nutrients can be destroyed if vegetables are overcooked	1	2	3	4	5
45	Eating oatmeal may decrease the risk of heart disease	1	2	3	4	5

46	Carotenoids work to prevent the formation of free radicals	1	2	3	4	5
47	Natural and organic foods are more nutritious than foods grown under conventional methods	1	2	3	4	5
48	Dehydration can impair physical performance	1	2	3	4	5
49	During activity, thirst is an adequate guide for the need for fluids	1	2	3	4	5
50	During exercise, mass ingestion of large amounts of fluids is preferred over frequent ingestion of small amounts	1	2	3	4	5
51	An athlete should drink no water during practice, but rather rinse out his/her mouth or suck on ice cubes	1	2	3	4	5
52	Sports drinks are the best way to replace body fluids lost during exercise	1	2	3	4	5
53	Alcohol consumption can affect absorption and utilization of nutrients	1	2	3	4	5
54	Alcohol has more calories per gram than protein	1	2	3	4	5
55	Caffeine has been shown to improve endurance performance	1	2	3	4	5
56	Caffeine can increase the risk of dehydration	1	2	3	4	5
57	An athlete involved in endurance events (e.g. distance running) should follow a considerably different diet than one participating in events of short duration (e.g., sprinting)	1	2	3	4	5
58	A physically fit person eating a nutritionally adequate diet can improve his/her performance by consuming greater amounts of nutrients	1	2	3	4	5
59	A muscular person expends more energy at rest than a non-muscular person of the same age, sex and weight	1	2	3	4	5
60	A 200-pound person uses about twice as many calories to run a mile as a 100-pound person	1	2	3	4	5
61	A person with a higher percentage of body fat may weigh less than a person of the same size with a greater muscle mass	1	2	3	4	5
62	A sound nutritional practice for athletes is to eat a wide variety of different food types from day to day	1	2	3	4	5
63	Skipping meals is justifiable if you need to lose weight quickly	1	2	3	4	5
64	When trying to lose weight, acidic foods such as grapefruit are of special value because they burn fat	1	2	3	4	5
65	If trying to lose weight, carbohydrates should come only from fruits and vegetables rather than from breads and pastas	1	2	3	4	5
66	The relationship of good eating habits to good health should be stressed to the athlete	1	2	3	4	5
67	Coaches need to have good attitudes toward nutrition because of their close contact and influence upon athletes	1	2	3	4	5
68	The type of food an athlete eats affects his/her physical performance	1	2	3	4	5
69	What the athlete eats is only important if the athlete is trying	1	2	3	4	5

	to gain or lose weight					
70	Nutrition is more important during the competitive season than during the off-season for the athlete	1	2	3	4	5
71	Food advertisements are a very reliable source of nutritional information	1	2	3	4	5
72	It is the coach's responsibility to stress good nutritional practices	1	2	3	4	5
73	The athlete should schedule his/her activities so he/she has time to eat	1	2	3	4	5
74	Learning about nutrition is not important for athletes because they eat so much food they always get the nutrients their bodies need	1	2	3	4	5
75	Learning facts about nutrition is the best way to achieve favorable changes in food habits	1	2	3	4	5
76	Nutritional counseling would be important to the athlete who is trying to change his/her weight	1	2	3	4	5